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THE MORRIN
"CLIMAX"
WATER TUBE
BOILER
(PATENTED)

New

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THE MORRIN

“CLIMAX”

WATER TUBE

SAFETY BOILER

PATENTED





THE UNITED STATES OF AMERICA

THE WORLD'S COLUMBIAN COMMISSION

BY ACT OF THEIR CONGRESS HAVE AUTHORIZED
AT THE INTERNATIONAL EXHIBITION HELD IN THE CITY OF CHICAGO, STATE OF ILLINOIS, IN THE YEAR 1893,
TO DESIGN A MEDAL FOR EXHIBITS ABOUT WHICH IS SET FORTH ABOVE UPON THE PLATE OF AN INTERNATIONAL
JUDGE ACTING AS AN EXAMINER UPON THE FINDING OF A MEDAL OF INTERNATIONAL JUDGES, TO

CLONBROCK STEAM BOILER WORKS,
BROOKLYN, N. Y.

EXHIBIT: STEAM BOILERS.

AWARD

For vertical water tube type, to form resembling the letter "U" and carrying from a central vertical shell to drum. The two ends of shell are expanded into the shell at bottom and at top at different levels and separated by an angle in the vertical surfaces. The entire space around the drum is filled with a network of tubes. About 25 per cent of the total heating surface is above the water line. Baffle plates are provided in the upper space of the drum, supporting the top ends of the tubes and of tubes to insure circulation of steam. Central drum extends some distance above upper shell to increase volume of steam power. Boiler is enclosed in a non-combustible shell, linked together with sections being fixed with bolts and secured by rivets. Exterior can be rapidly taken down in any desired position for removal of tubes and other repairs. External shape of boiler is in the form and arrangement of tubes. There is a set of 1,000 horizontal water tubes exhibited in one long above the boiler. The tubes are of varying lengths, the total area of heating surface being one thousand square feet, or fifty times the area of the boiler. One-fourth of the tubes are of the type of the boiler. The tubes are of varying lengths, the total area of heating surface being one thousand square feet, or fifty times the area of the boiler. One-fourth of the tubes are of the type of the boiler. It thus passes in between all shells (as a view part of which serves as a model drum. Boiler exhibited showed considerable expansion from what appeared beyond its normal capacity, and is especially noticeable from the fact that it is a large fire drum, open at the top, and of horizontal boiler added to carrying high pressure.

JOHN A. KOEHL, President, International Commission

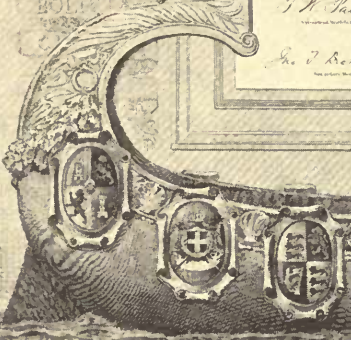
John A. Koehl
President, International Commission

J. A. Koehl
President, International Commission

John A. Koehl
President, International Commission

V. KIRPICHOFF, Individual Judge

John A. Koehl
President, International Commission



CATALOGUE

— OF —

THE MORRIN “CLIMAX”

WATER TUBE

SAFETY BOILER

(PATENTED.)



Manufactured by

The Clonbrock Steam Boiler Company,

General Offices and Works:

BROOKLYN, N. Y.

1896.

TJ315
M7C5



78306



MEDAL AWARDED AT
WORLD'S COLUMBIAN EXPOSITION, CHICAGO, 1893.

The Clonbrock
Steam Boiler Company,
BROOKLYN, N. Y.

GENERAL AGENTS AND —————
————— MANUFACTURERS OF

The Morrin "Climax"
Water Tube —
Safety Boiler

(Patented)

For the United States.



THOMAS MORRIN,

Mills Building,

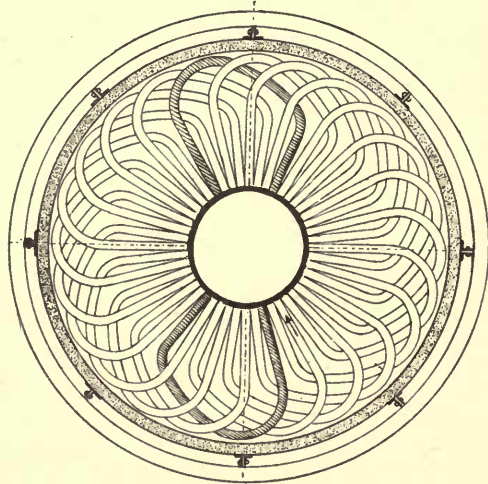
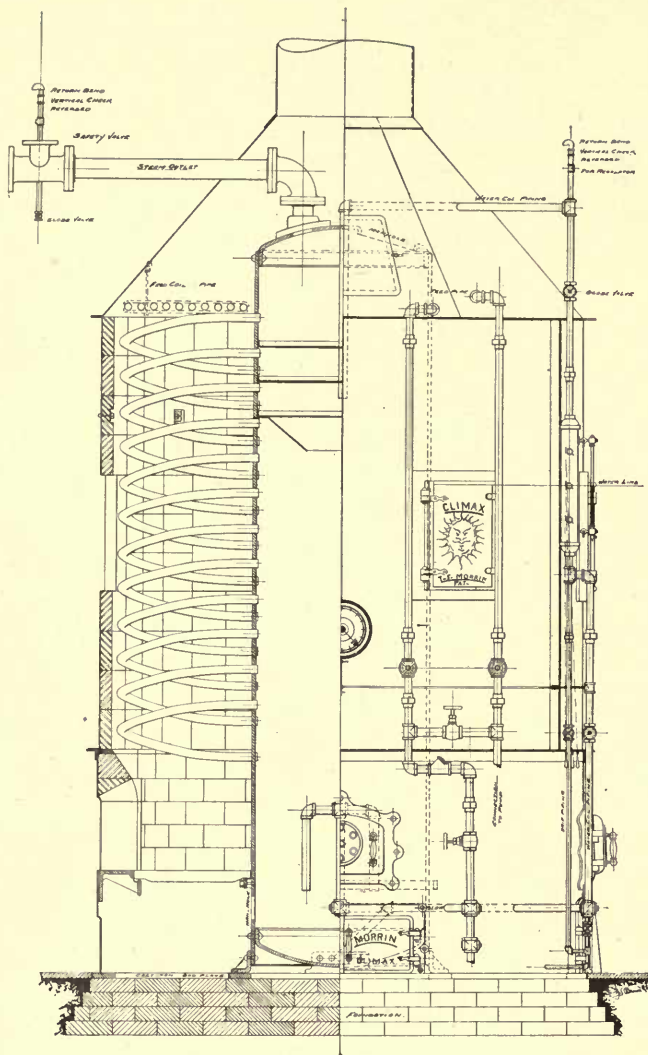
AGENT —————

SAN FRANCISCO, CAL.

For the States of WASHINGTON, OREGON,
CALIFORNIA and NEVADA.



SPECIFICATIONS, DRAWINGS, &c., FURNISHED.



250 H. P. MORRIN "CLIMAX" BOILER.

The Morrin "Climax"
Water Tube Safety Boiler

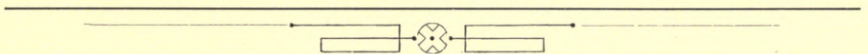
IS ESPECIALLY ADAPTED

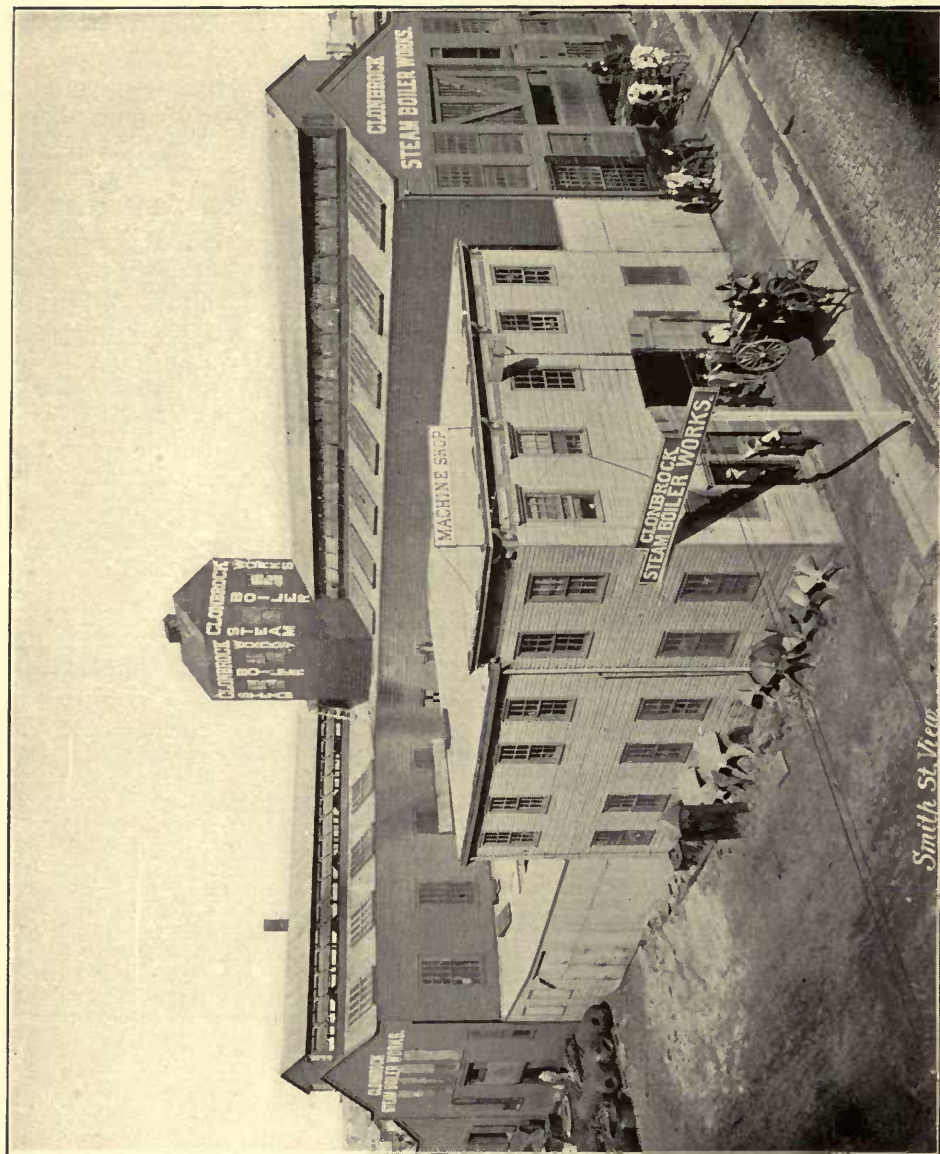
FOR THE UTILIZATION OF

*Waste Heat from Cylinder Boilers,
Blast Furnaces and Forges,*

AND FOR BURNING 

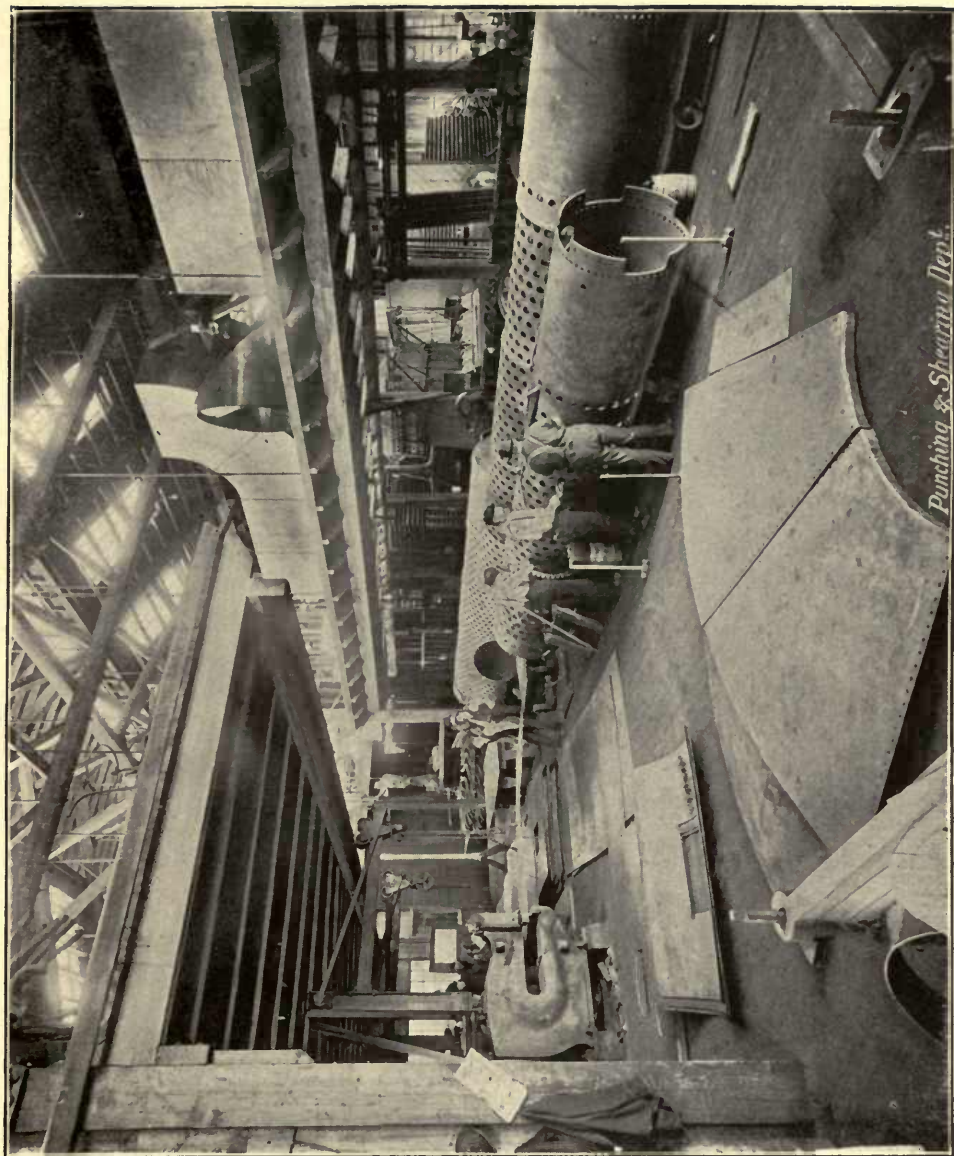
Green Bagasse.



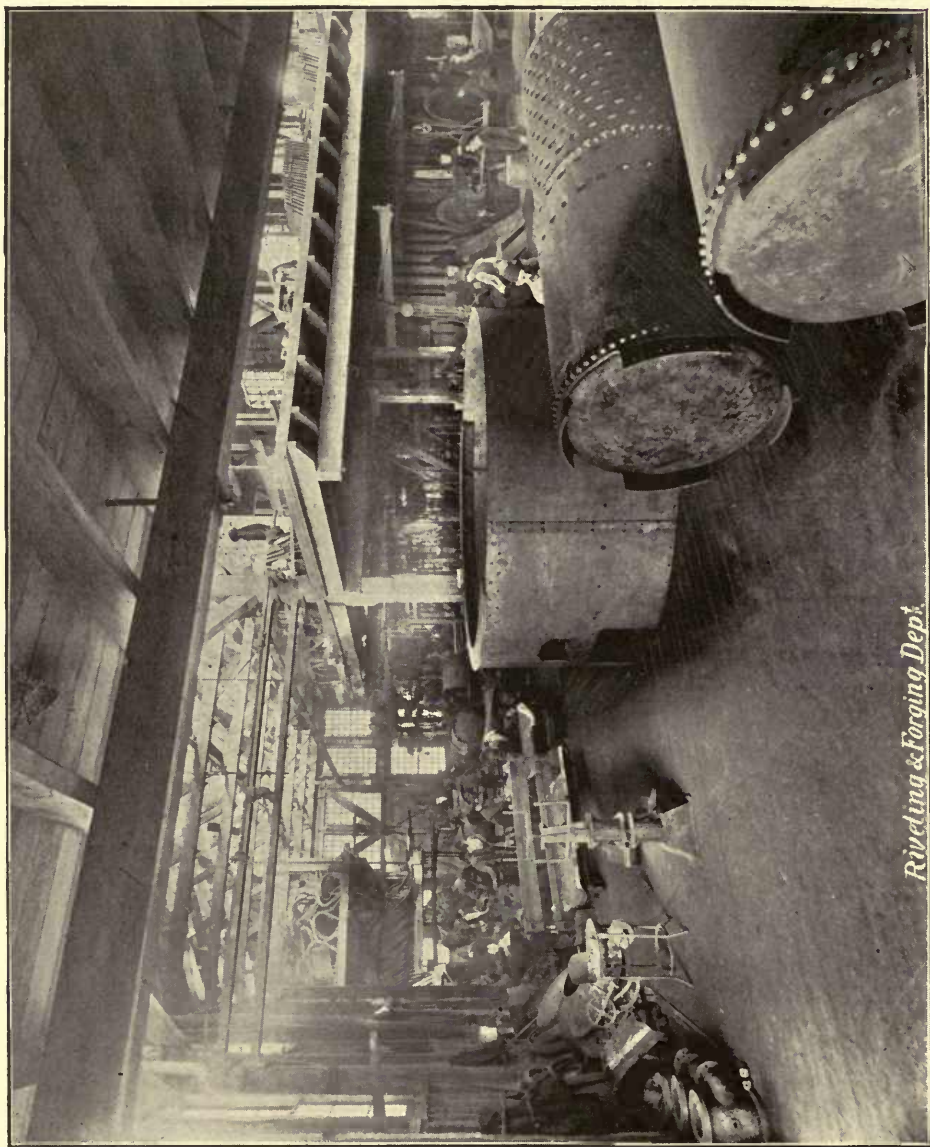


Smith St. View

WORKS OF THE CLONBROCK STEAM BOILER CO.

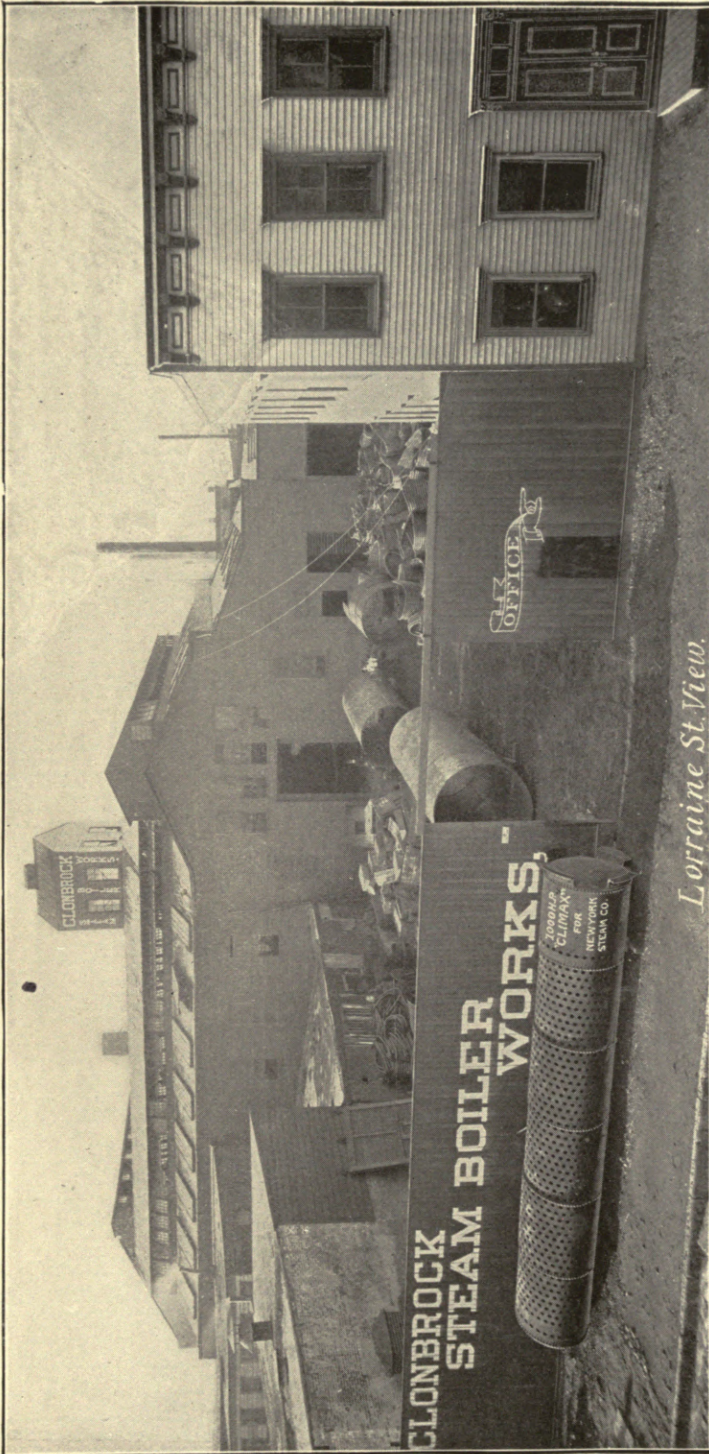


WORKS OF THE CLONBROCK STEAM BOILER CO.



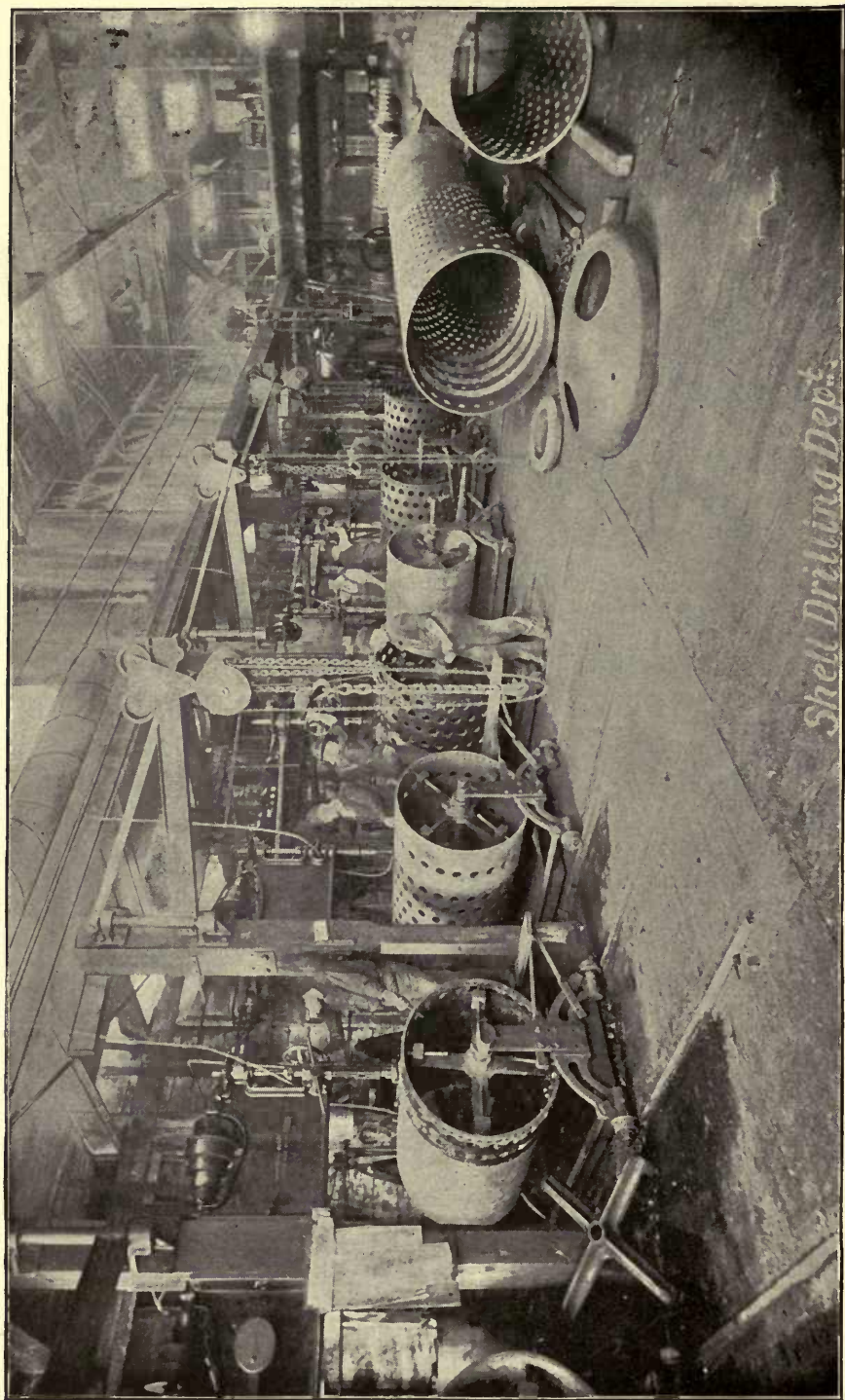
Riveting & Forging Dept.

WORKS OF THE CLONBROCK STEAM BOILER CO.



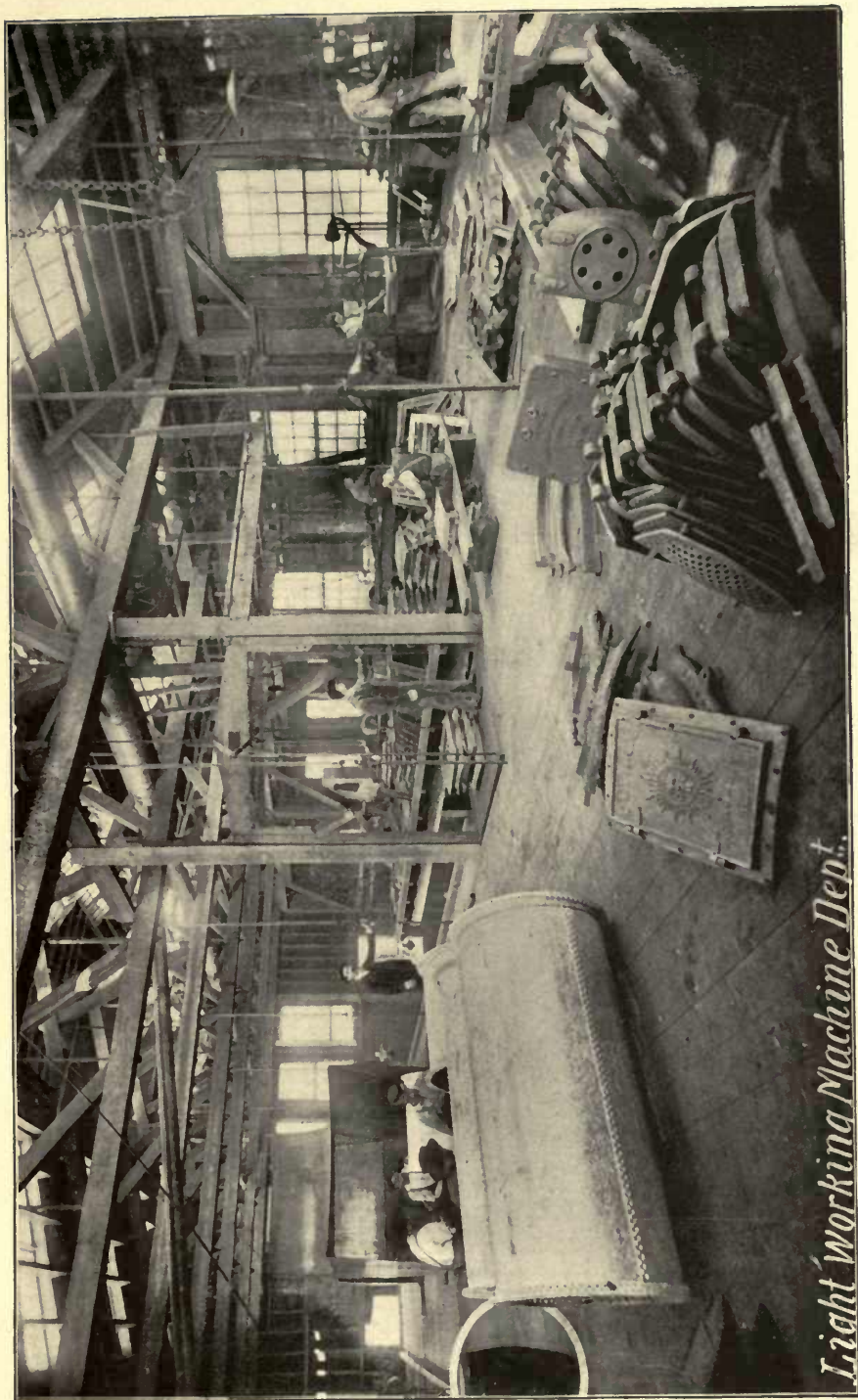
Lorraine St. View.

WORKS OF THE CLONBROCK STEAM BOILER CO.



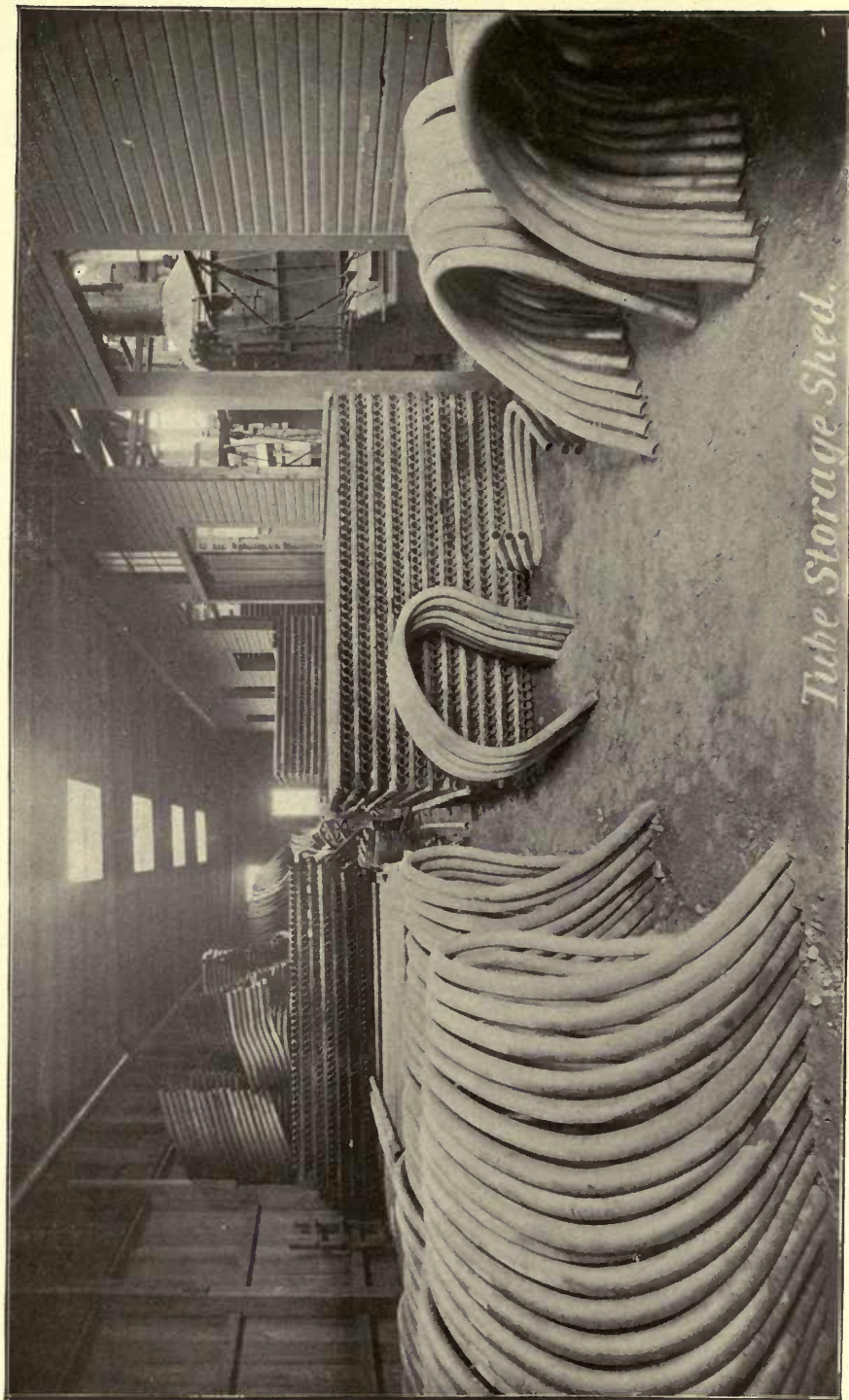
Shell Drilling Dept.

WORKS OF THE CLONBROCK STEAM BOILER CO.

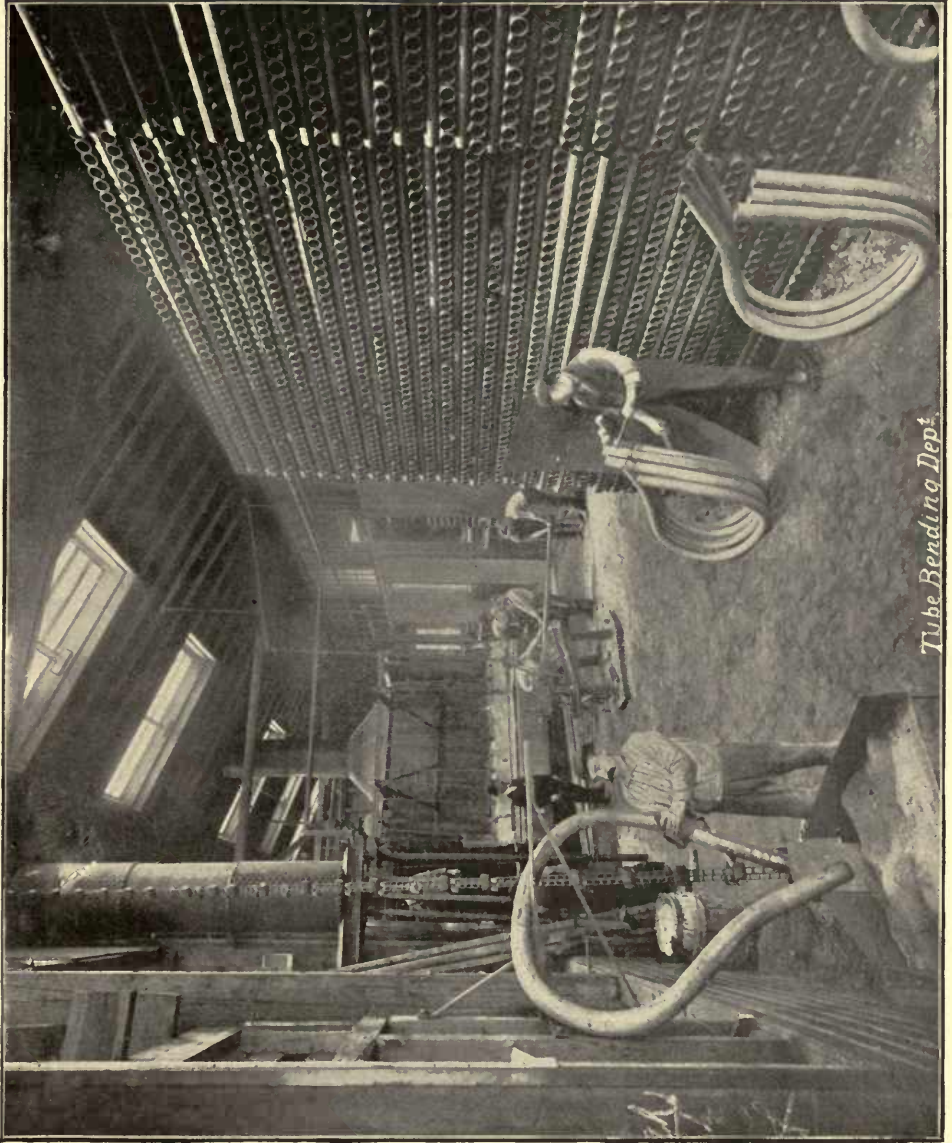


Light working Machine Dept.

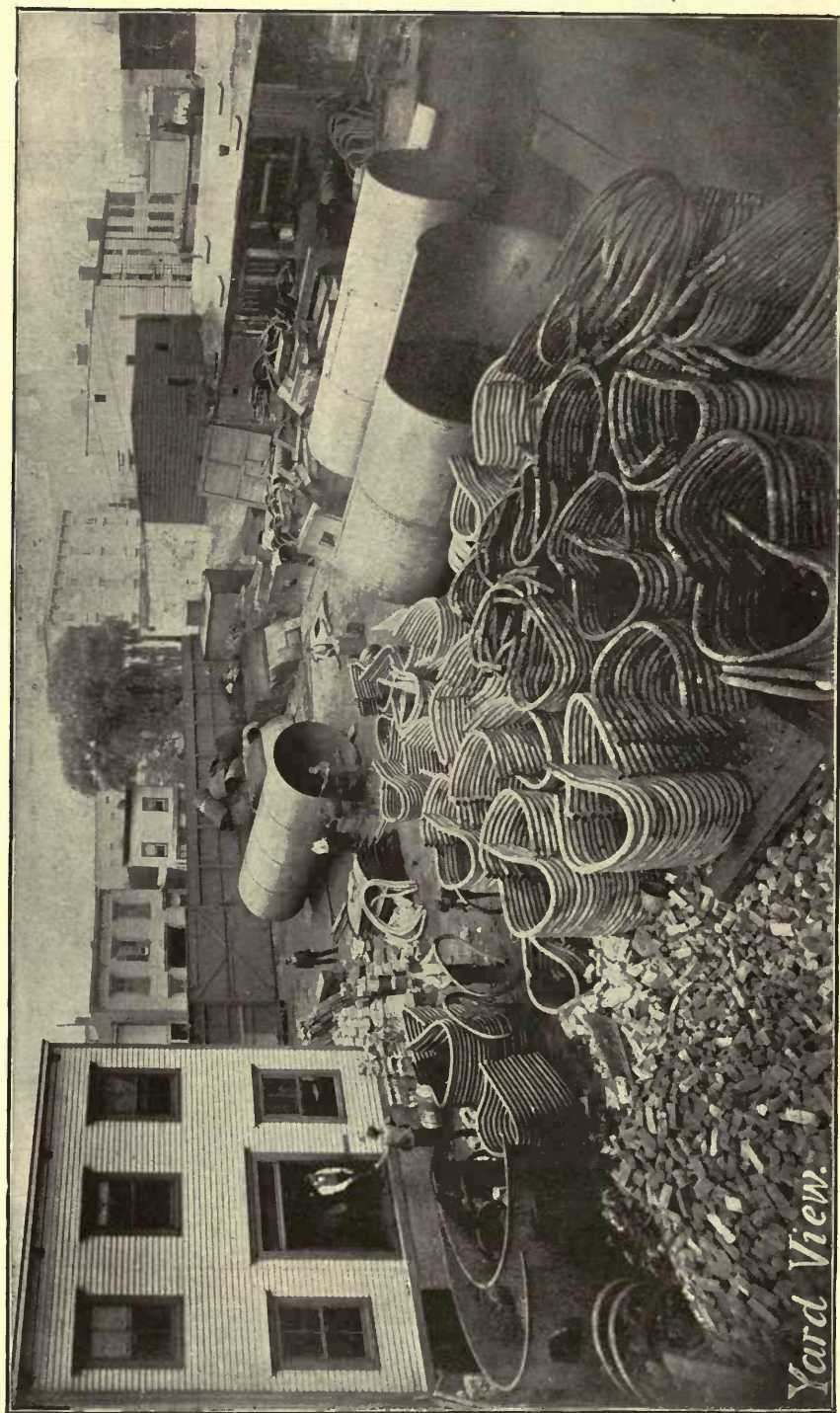
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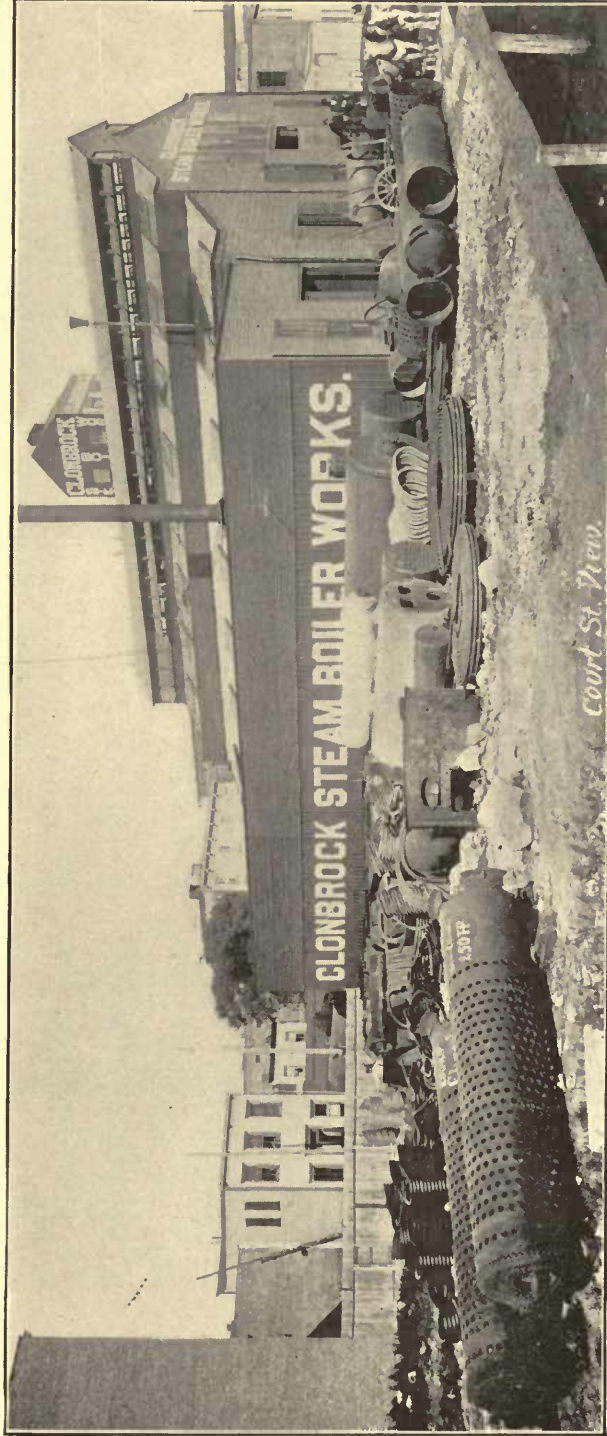
WORKS OF THE CLONBROCK STEAM BOILER CO.



Tube Bending Dept.



WORKS OF THE CLONROCK STEAM BOILER CO.



Court St. View.

WORKS OF THE CLONBROCK STEAM BOILER CO.



THE COLUMBIAN EXPOSITION

THE BOARD OF LADIES TO PROMOTE THE
 World's Columbian Commission, by virtue of the authority
 vested in it by an Act of the Congress of the United States
 of America, confer this **Diploma of Honorable Attention**
 upon **GEORGE DEANER'S MUSEUM**
 a Certificate having been filed with said Board stating that
 the said well as

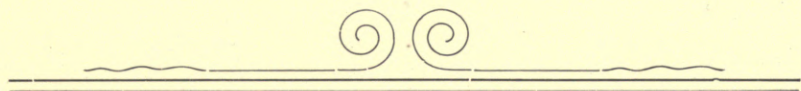
Director of the Denver Palace
 assisted in the production and perfection of the exhibit of
GEORGE DEANER'S MUSEUM, WORKS - DENVER -
 which received an Award at the World's Columbian Exposition,
 which our hands and seal this **22nd** day of **DECEMBER**, 1892
 in the City of Chicago.



Virginia C. Meredith
 Chairman of the Committee on Exhibits

Barbara Annie Palmer
 President of the Board of Lady Managers

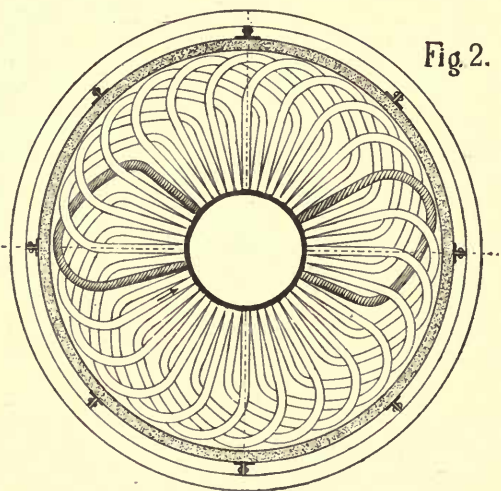
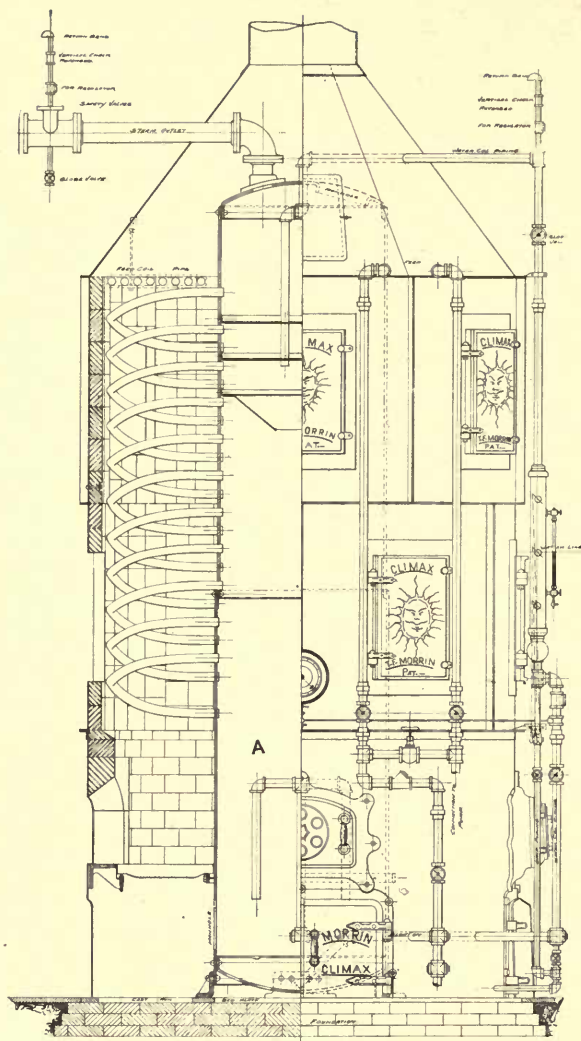
Geo. R. Davis
 Director General of the Columbian Exposition



WE take pleasure in presenting to you the accompanying cuts, description and partial list of installations, also valuable testimonials, which are fair illustrations of the estimate made of the Morrin "Climax" Steam Boiler, by some of the prominent parties using it.

Brooklyn, Nov. 15, 1896.







DESCRIPTION

—OF—

THE MORRIN "CLIMAX" WATER TUBE SAFETY BOILER.

A CASUAL glance may give the impression that this generator is very complicated, but a close examination will reveal it to be of very simple construction; and when its construction is understood, it will also be apparent that with the ordinary amount of care, such as is usually bestowed upon common boilers, it is not liable to get out of order, and when, through constant use repairs are demanded they can be easily and quickly made.

The boiler consists of a vertical cylinder and loop-like tubes, extending the entire height of the generator, which comprise the principal heating surface, as shown in Figs. 1 and 2.

The main cylinder (shell) *A* is constructed similar to any cylindrical boiler shell, and is made perfectly steam-tight, also strong enough to resist internal pressure, and is provided on top with a man-hole plate. A perfect idea of the loop-like tubes may be obtained by referring to the shaded tubes in Fig. 2. The extremities of these tubes extend and are expanded into the cylinder *A*, forming a steam-tight connection. Their ends are in higher planes to each other as will be seen by referring to the lower shaded tube in Fig. 1. The heads are bumped to a radius equal to the diameter of the shell and require no braces. The tubes are $1\frac{1}{2}$ to 3 inches in diameter, and 280 to 1,000 in number, according to the size of the boiler, and their aggregated length varies with the size of the boilers from 1,000 to 12,000 feet, or equal to about two and a quarter miles in the largest size.

These tubes are bent as shown in Fig. 2, and re-enter the cylinder about eighteen inches higher than their initial entrance.

The central drum below the fire level affords a settling space for sediment. Access to this drum is obtained by a full sized man-hole. It is simple in construction, presents a plain surface without braces and can be readily cleaned.

In the main cylinder a short distance above the water level, a

deflector plate is inserted, which tends to throw back any water that may be carried by the steam, and a series of diaphragms divide the upper portion of the cylinder forming a series of superheating chambers, through which the steam is successively compelled to circulate by the connecting loop-like tubes, thus becoming thoroughly dried and superheated. The steam thus generated passes into a reservoir, which is provided for above the top row of tubes. This is made perfectly clear to the reader by referring to Fig. 1. As the boiler increases in size so also do the water and steam spaces in the same ratio. The same cannot be said of any other boiler on the market.

Above the central shell, resting on the row of tubes, is a coil 100 to 300 feet in length, according to the size of the boiler, of $1\frac{1}{2}$ to 3 inch pipe. This coil is welded and without screw joints. The feed water flows through this coil or economizer before entering the boiler, and thus absorbs considerable heat from the waste gases; it then passes to the main cylinder, thence into the curved tubes, in which a rapid circulation is maintained by reason of their upward course and the intense heat by which they are surrounded.

The fire box surrounds the large vertical cylinder, and is annular in form. It is enclosed in a casing of iron, which is bolted together in sections, and lined with a patent fire brick. It may be said of this brick that wherever used it has met with the greatest appreciation and praise from the parties having charge of the boiler plant. The height of fire chamber adds largely to perfect combustion. Ordinarily three or four fire doors are provided, according to the size of the boiler.

The construction of the cylindrical shell into which the tubes are inserted is the same as that of any boiler shell, with the exception that it is welded longitudinally instead of riveted, allowing of a uniform spacing of the holes for the tubes. The tubes are bent to a template and expanded into the shell in the usual manner. The heating surface is efficient, and evaporates with a rate of combustion of 12.5 pounds of coal per square foot of grate per hour, 6 pounds of water per square foot of heating surface per hour, requiring less than 5 square feet of heating surface per horse power, on a basis of 30 pounds of water per horse power per hour. The ratio of grate to heating surface is very effective, consequently steam is rapidly formed and a high economy of fuel obtained.

Since the largest diameter exposed to bursting pressure is the small, vertical cylindrical shell, these generators can be of large power and still be entirely safe under any pressure desired. The factor of safety in this boiler is very high.

One of these boilers has been under steam day and night for eight years, and shows no sign of failure anywhere; a tube which was cut out for examination during the season of 1894 was in as good condition as when first put in. A tube more recently removed from the same boiler thoroughly substantiates the foregoing claim.

SCIENTIFIC CONSTRUCTION.

It is more compact than any other boiler in use. The bent tubes and the main shell are filled with water, and the heat circulates amongst the tubes, around the outer shell and thence to the flue. No other possible arrangement of the same amount of material could give as much heating surface in so small a space. The heat is almost entirely absorbed before it reaches the stack, and the loss from radiation is very slight. The water and steam heating surfaces are in proper proportion to each other, thus making it possible to generate dry steam in a very short time.

The patent smoke preventing fire brick in the furnace add largely to the item of economy by promptly igniting the gases of combustion.

SAFETY.

The alarming loss of life and property resulting from the explosion of steam boilers calls imperatively for a construction that shall, as far as possible, be absolutely safe under all ordinary conditions of use. To meet this demand, the parts exposed to steam pressure must be of such a form and dimensions as to give a factor of safety large enough to remove all likelihood of their failure, even if temporarily subjected to pressure materially in excess of that ordinarily employed.

If from carelessness there should be a heavy fire in the furnace and low water in the boiler, the worst that could happen would be the rupture of one of the tubes ; this would release the pressure immediately without serious injury or disaster.

ECONOMY.

In considering the economy of a Steam Boiler several things must be taken into account. For example, Economy of Space calls for the maximum effect of a given amount of room occupied. This is often of great importance, and is always deserving of careful attention. Again, economy with the least consumption of fuel. Neither of these considerations should be lost sight of, although their relative importance may alter under different circumstances.

All steam users should remember that a small saving each day will amount to a considerable sum in a year, and, therefore, those who contemplate putting in a new boiler or changing their old plant should seriously consider the item of economy in fuel. More judgment and consideration are needed in selecting a boiler that will combine high efficiency with economy in fuel than in the selecting of an engine.

The Morrin "Climax" is specially designed to meet this requirement.

DURABILITY.

Of almost equal importance to the fuel economy of a boiler is the question of durability. Liability of all parts to fail, rendering frequent stoppage for repairs necessary must be carefully considered. While such repairs are costly in themselves, the loss caused by the enforced stoppage is often greater.

Though the strength and compactness of the "Climax" boiler reduces its liability to accident and necessity for repairs to a minimum, yet it has been constructed so that every part of it is accessible.

The joints are protected from injury, being under water and removed from the action of the flame. The tubes being expanded in the main shell allows for unequal expansion and contraction, and the bends provide for unequal expansion in the individual tubes. They are not only less liable to injury, but any tube can be replaced easier, at less expense and in less time than in any other boiler.

Another great element of safety and durability in the "Climax" Boiler lies in the fact that only the best materials and workmanship are employed in its construction. No cast metals are used (which are liable to give way at any moment) but only the best quality of steel and wrought iron.

EVAPORATION.

This boiler under equal conditions will evaporate more water per pound of fuel than any other boiler in the market; over one hundred tests have demonstrated this. A great saving results from the heating surface being always clean, and arranged so as to receive the best possible effect of the heat; in addition to this the steam and water spaces are so ample that bad water and almost any kind of fuel can be used successfully.

STEADINESS OF WATER LEVEL.

The ample passages for circulation secure steadiness of water level unsurpassed by any other boiler on the market.

STEAMING QUALITIES.

The steaming qualities of this boiler place it beyond comparison with any other type of boiler. This has been demonstrated by innumerable tests. In some instances we have raised one hundred and twenty-five pounds of steam from cold water in ten minutes. This record has never been reached by any other type of boiler. The "Climax" has been subjected to some of the severest tests known; for instance, in a rolling mill, where the load varies from ten to five

hundred horse power, this boiler has withstood the sudden call for power without the pressure varying one pound. In most boilers, when the fires are cleaned, the pressure invariably falls, and it is only with great exertion on the part of the fireman that steam can be raised to the point at which it was originally before the fires were drawn. In the "Climax" this is very different; fires can be cleaned and furnace door left open for any reasonable time without pulling down the steam.

This should be carefully considered before the selection of boilers is made. Steam from this boiler is not only absolutely dry, but is superheated to over eighty degrees.

Recent tests made by the Pennsylvania Railroad Company and others prove this claim.

ACCESSIBILITY.

The boiler is constructed with man-hole plates at the top head and in the lower shell. Each section of the outside casing of the boiler is provided with a cleaning door, through which the ashes and soot may be blown off the tubes by means of a steam hose. A tube may be readily removed and another substituted. The outside casing of the boiler being sectional and simply bolted together can be easily removed for this purpose. The operation of removing and substituting a tube can be performed in one and one-half hours. By opening one man-hole access is gained to every part of the interior of the shell, to both ends of the tubes and to the interior of each tube.

CLEANLINESS.

The "Climax" being a vertical boiler, is admirably constructed so that all sediment settles to the mud-drum, from which it can be readily and frequently blown out. The interior of the boiler is, therefore, almost self-cleaning.

DRAFT.

As thin, clean tubes receive the first, the best and the last attack of the heat, the draft is always good and not impeded by soot. The outside shell is not in contact with the heat, therefore no blistering of plates nor deposit on the heating surfaces.

ECONOMY OF FLOOR SPACE.

The boiler occupies less floor space than any other type of boiler on the market. A 1,000 horse power "Climax" Boiler occupies a diameter of only seventeen feet, smaller units less in proportion.

REPAIRS.

The construction of this boiler is such as to require very few repairs; but should it be found necessary to make them, they can easily and readily be done by a good mechanic with the tools usually found in the store room.

The necessary tools to make any repairs are an ordinary expander tool, hammer and cape chisel and a tackle for removing any upper sectional casing above the furnace.

ERECTION.

In erecting this boiler, the central or main shell is stood upon the cast iron foundation plate, which is set upon the masonry. The foot castings attached to the main shell are then secured to the foundation plate by means of tap bolts. After this operation, the work of placing the tubes in the shell is commenced. After all the tubes have been properly expanded, the whole is subjected to a hydrostatic test of 300 lbs. to the square inch.

Should it be necessary to remove one or more tubes from the boiler after the test has been made on account of a pin hole or sand spot, the water is run out of the boiler and a new tube inserted, which is done in a very few minutes. The tubes are again tested to see that those inserted have been properly expanded. This operation completed, the work of placing the casings, which have been lined with the porous fire brick during the period of placing and testing the tubes, are then placed in position and securely bolted. The canopy or bonnet is next placed, and thus the work of completion goes on until every part is in its proper position.

The time consumed in the erection of any one of these boilers averages about three weeks, so that a person ordering a boiler can have steam on his plant within six weeks from date of placing the order. The same cannot be said of any other type of boiler now on the market.

TRANSPORTATION.

The "Climax" is very easily handled, all parts being sectional. The heaviest of the sections does not weigh over 500 lbs., while the main shell varies in weight from two to eight tons according to the size of the boiler.

The tubes are packed in bundles of six to eight, the casings and furnace sections crated. All fittings, bolts and minor parts are boxed so that they can be conveniently and easily handled.

We have on file some very strong letters from our foreign customers, testifying to the very easy manner in which the "Climax" can be transported from the steamer to the plantation.

SUMMARY.

THE "CLIMAX" BOILER

Is constructed with especial reference to fulfilling all the requirements afore named. As to safety, there are no large diameters exposed to pressure, hence the ultimate strength is far in excess of the strain to which the metal is subjected. Only the best material is used, and the workmanship is the best. For economy, the disposition of the heating surface is such as to utilize the maximum of heat from the fuel burned, preventing loss of heat and providing large power in small space.

In truth it can be justly claimed that it embodies all the absolutely essential features now required and demanded by engineers and steam users.

Its record wherever used, in rolling mills, flour mills, cotton mills, sugar refineries, rope walks, electric light and power plants, and for heat and power in some of the largest manufacturing plants in the United States, is the best proof of its superiority, and of the justice and value of our claims.

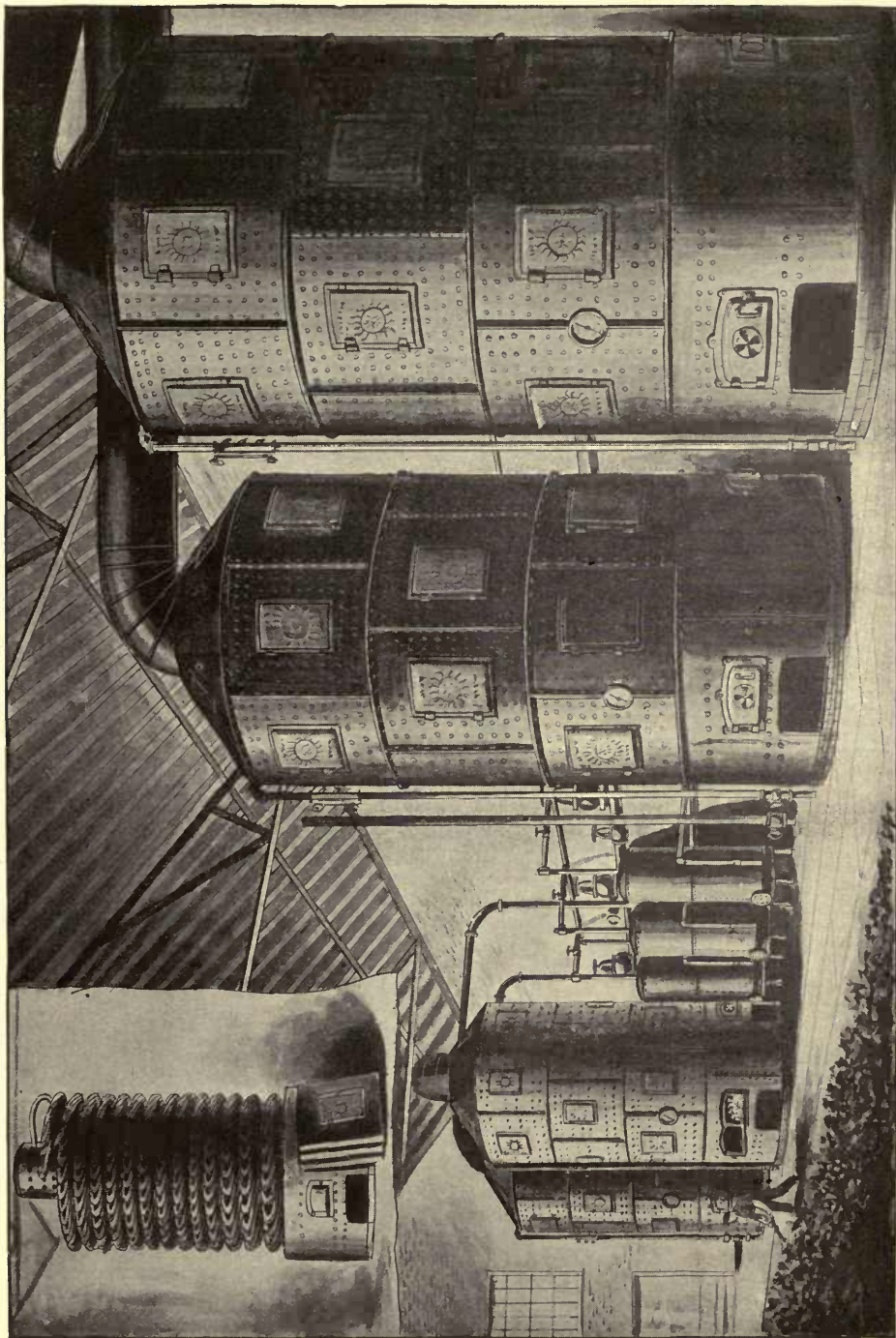
As it is superior to all other boilers on the market, and as it will reduce expense largely and remove danger to life and property, your interests will be materially enhanced and profits increased by adopting the "Climax."

NOTE.

The "CLIMAX" has no Screw Joints, no Metallic Joints, no Ground Joints, no Packing Joints, no Cast Iron Pipes, Manifolds or Headers to cause trouble from unequal expansion and contraction.

The "**CLIMAX**" is made in sizes from 50 to 1,000 horse-power.

Having thus briefly noted a few of the principal features of our boiler, your personal investigation and examination of every claim made is solicited. Any information desired will be cheerfully given.



STATION OF THE BROOKLYN CITY AND NEWTOWN R. R. CO., BROOKLYN, N. Y., CONTAINING SIX 350 H. P. MORRIS "CLIMAX" BOILERS.

A Great Invention.

From THE MERCANTILE TIMES, New York, May 23d, 1891.

It seems to be generally agreed by those who are looked upon as really competent authorities upon such matters, that the Morrin "Climax" Steam Generator is one of the really great inventions of the age. It is safe, durable and economical to a really remarkable extent and never fails to give the most complete satisfaction to those who use it. It is made in sizes from 50 to 1,000 h. p., and is adapted to every kind of work within those limits. It has no screw joints, no metallic joints, no packing joints, no cast iron pipes, manifolds or headers to cause trouble from unequal expansion and contraction. If we had space we would like to print an engraving of this generator, and at some future time will probably do so. At present, however, it must suffice to say that the "Climax" is constructed with a special view to fulfilling all the requirements of safety, economy and durability. As to the safety, there are no large diameters exposed to pressure, hence the ultimate strength is so far in excess of the strains to which the metal is subjected as to meet every requirement. None but the best of material is used and the workmanship is of high standard. Regarding economy, the disposition of the heating surface is such as to utilize the maximum of heat from the fuel burned, thereby avoiding loss of heat and providing large power in small space. With reference to durability, the construction is such as to issue a rapid circulation, which is one of the most important requisites—and there are no parts subject to undue strains, or that are restrained from freely expanding and contracting as they must do when in use. There are no joints to cause trouble by leaking, and in all respects the construction is simple and without complication. The closest scrutiny of every claim made for this boiler is requested, and any information desired will be cheerfully given at the works of the makers, or at any of the branch offices.

The "Climax" has been on the market for several years, and from the first it has more than justified all the claims that have been made on its behalf. The demand for it keeps on growing very steadily from year to year, and that the outlook ahead could not well be better than it is.

The Morrin "Climax" Steam Generator is the invention of Mr. Thomas F. Morrin, a thoroughly practical man of many years' experience, and is built at the Clonbrock Steam Boiler Works, Brooklyn, N. Y. These extensive works, in which a force of over 500 hands is employed, are under the active management of a very able and popular gentleman long identified with this line of business. At the works, Marine and Stationary Engines and Boilers of every description are built and repaired.

The Morrin "Climax" Steam Generator is one of many specialties, and for which there is a continually growing demand.



The Largest Boiler in the World.

From THE STREET RAILWAY REVIEW, November, 1893.

To the west of the big boiler plant at the World's Fair, described several months ago in the Review, is another array of power producers hardly less interesting. This subsidiary plant was necessitated by the amount of power used.

Chief of interest in this above mentioned subsidiary plant was a pair of gigantic vertical water-tube Boilers, made by the Clonbrock Steam Boiler Works, of Brooklyn, N. Y., on the Morrin Climax System. A faint idea of the immensity of these generators may be gleaned from the engraving presented, but they must be seen to be realized.

This Climax display represented 3,000 h. p. One boiler was 1,500 h. p. capacity, the two were 700. The whole battery contained 20,000 square feet of heating surface. The two seven hundreds have 500 tubes each of 3" diameter, 11½ feet long. The large generator holds 1,000 tubes, of 3" diameter, 12 feet long, which if placed in a continuous line, would reach two and a half miles.

The three boilers installed by the Climax people are guaranteed to evaporate 60,000 pounds of water into dry steam, under actual, not ideal, conditions. The 1,500 h. p. boiler weighs, when ready for service, 181,000, and smaller, 131,000 pounds each. The large boiler occupies 198 square feet of floor space, while the smaller ones require 130 feet each. This type of boiler has been in service night and day for eight years, and on the general market for five years.

In street railway fields it has been particularly adaptable to trying conditions, and the number now in use in street railway power stations may be taken as representative of the future prospects of this generator.

Col. Jones, who has been in constant attendance and in charge of the exhibit, is a mechanical engineer of many years' experience, and has been untiring in his attention to visiting brethren, with all of whom he is very popular.

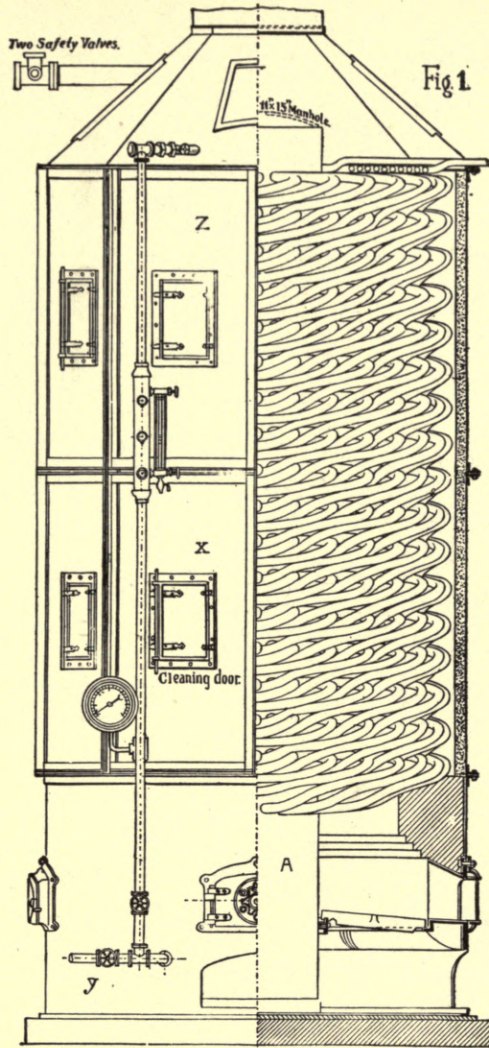


Fig. 1.

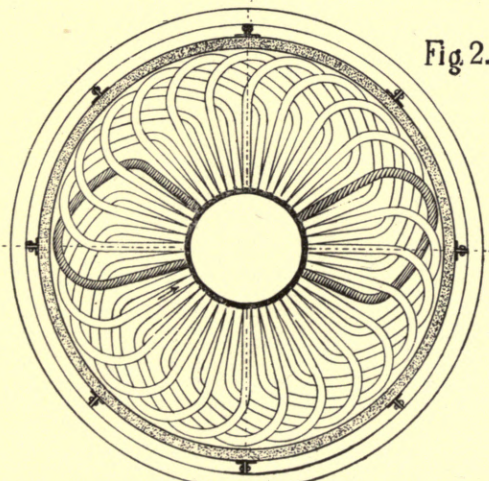


Fig. 2.

Utilization of Waste Heat from Cylinder Boilers.

Within the past two years the problem of how to utilize the waste heat from Cylinder Boilers has presented itself before the Mining Engineers of Pennsylvania, in such a positive manner as to cause several to take up the subject in earnest, and it may be of interest to the readers of this Catalogue to know just what steps have been taken, and what results have been obtained on this important subject.

The first gentleman to experiment in this line was Mr. Irving A. Stearns, General Manager of the Susquehanna Coal Co., and the several other companies controlled by the Penna. R. R., and the place selected for the experiment was in the rear of twelve cylinder boilers 30" in diameter, and 30 feet long, located at number two shaft boiler house of the Susquehanna Coal Co., Nanticoke, Pa.

By the means of the pyrometer, Mr. Stearns found the temperature of the gases going to waste in the stacks ranged from 1,500° to 2,000°: 1,500° with the blowers off; and 2,000° when on. This warranted him in seeing just how much of this waste heat could be utilized in making more steam, without altering the existing conditions of firing or using an ounce more coal. With this object in view he placed a 400 h. p. Morrin "Climax" Steam Generator (a vertical boiler, nothing more nor less than a large smoke-stack, 11 feet, 2" in diameter, and 26 feet 6" high, containing a heating surface of 3,940 square feet, made up of loop-like tubes, expanded into cylindrical shell, 42" diameter, by which a rapid and continuous circulation of water is maintained) between the two stacks that carried off the waste gases from the twelve cylinder boilers. Two brick flues conducted the gases to the Climax boiler. Entering at the base diametrically opposite to each other, the old stacks being temporarily cut off by iron doors, and the waste gases thus compelled to seek an outlet through the Climax Generator. The entrance to the Climax was also provided with iron doors in case it became necessary to clean it, which case the door leading to the stacks could be raised and the Climax Generator shut off.

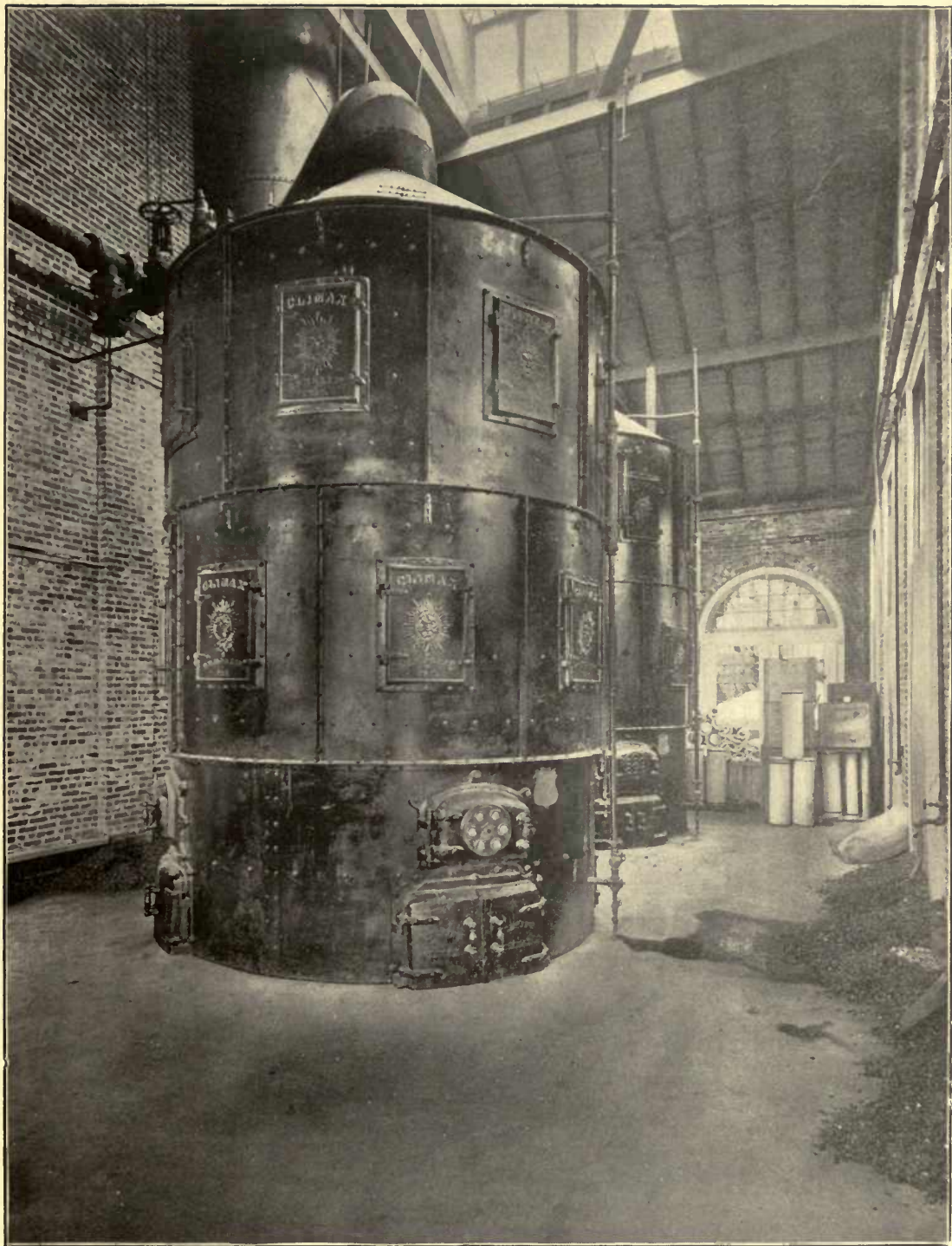
The results of tests on Climax Steam Generator, made on Feb. 21st, from waste heat alone, burning No. 2 buckwheat coal under cylinder boilers, is as follows:

Temperature of Feedwater, ...	150°
" " Feed Flue, ...	520°
Steam Pressure, ...	85 lbs.
Pounds of water Evaporated per Hour, ...	16,513 lbs.
" " " from and at 212°	18,171 lbs.
Horse-Power, Developed, Boilers Working under Blast, ...	526.7 H. P.

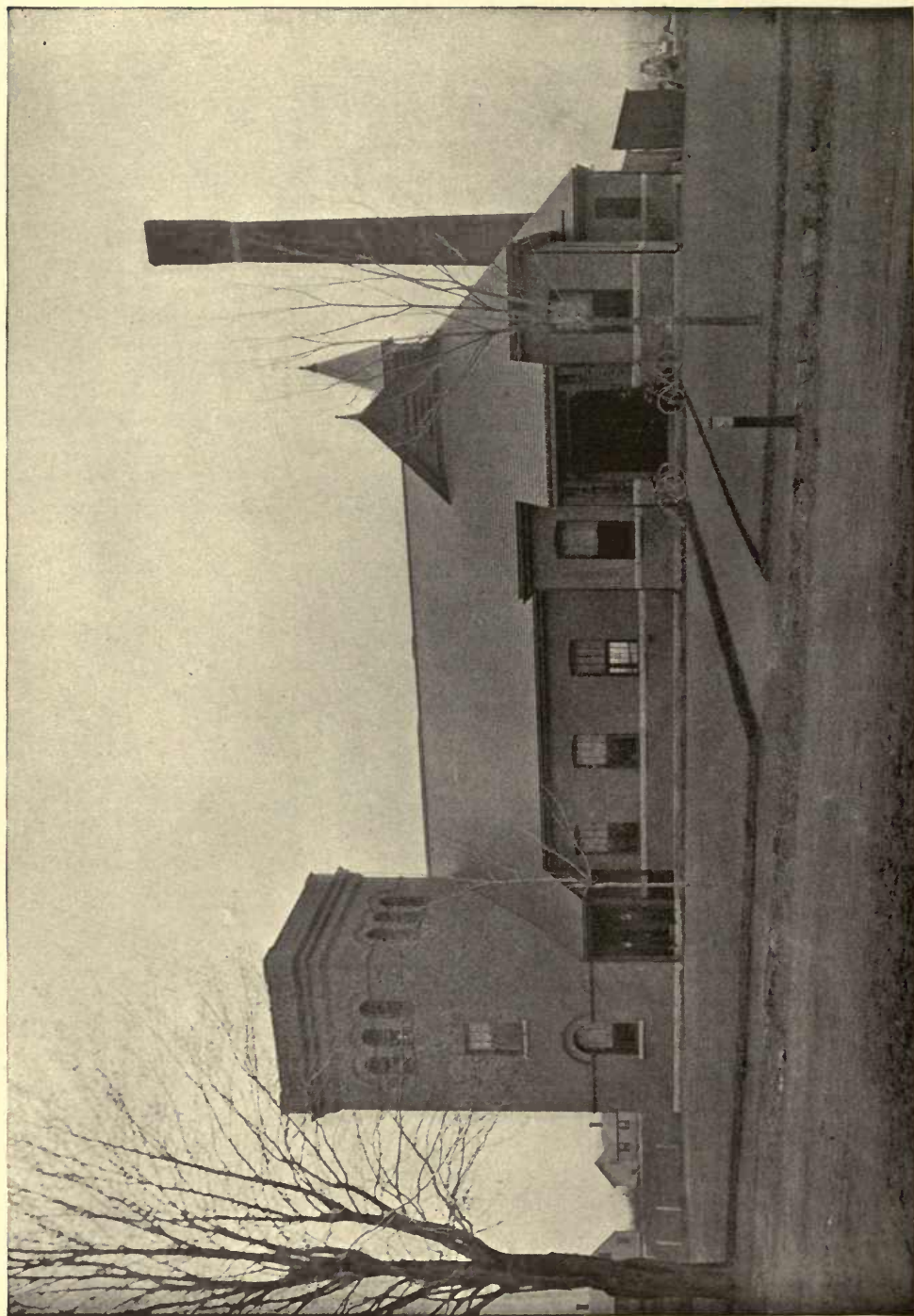
Horse-Power based on evaporation of 34 lbs. water per hour; from and at 212° 30 lbs.; from 100° feed to 70 lbs. steam.

The above results obtained by actual test afford some idea of the amount of heat going to waste and at the same time prove the value of the Climax Steam Generator for the utilization of same, for it can now be confidently asserted that where cylinder boilers are used it is possible to double the horse-power capacity without having to use an ounce more coal or employ another hand.

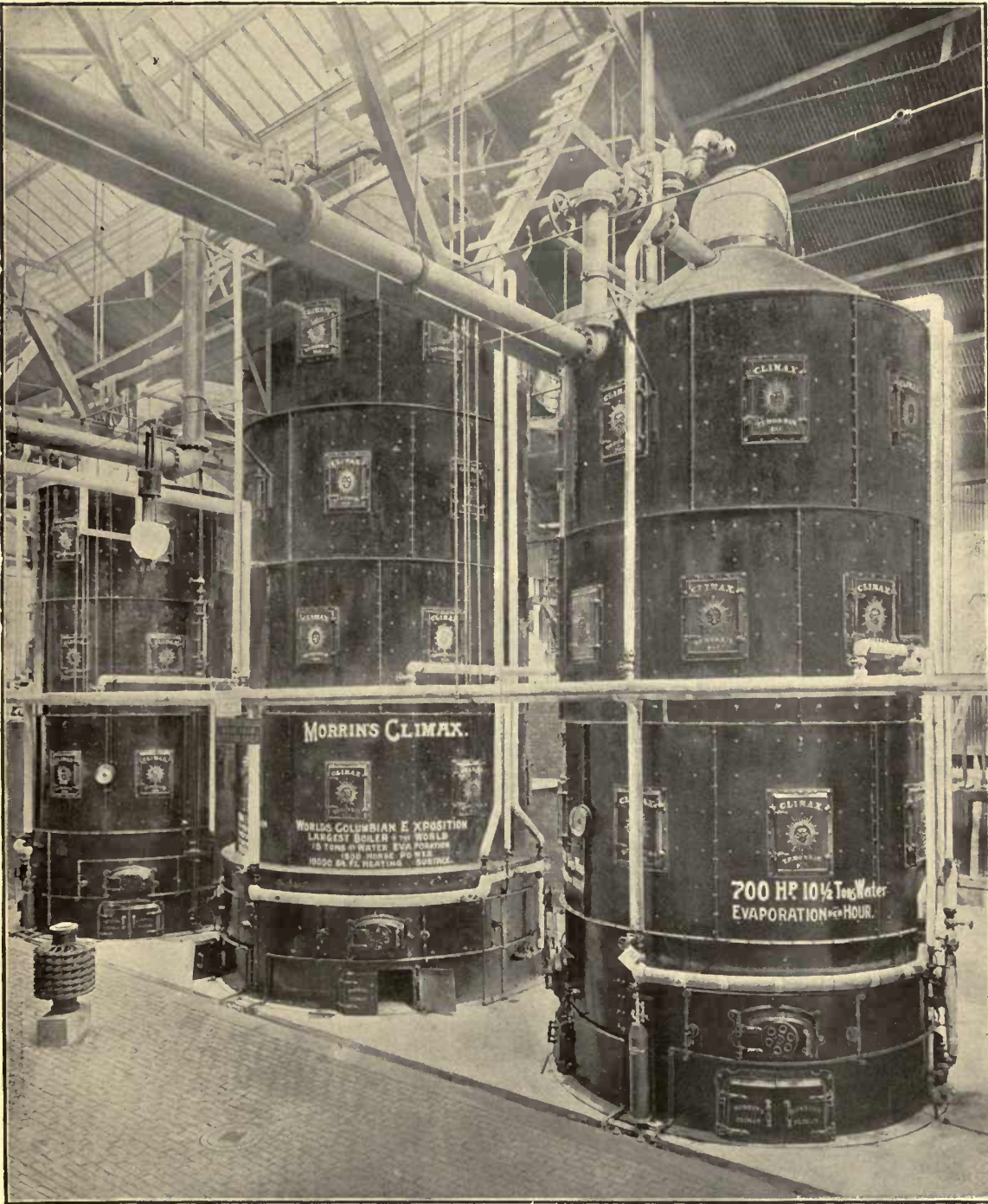
We will furnish upon application to the Mining Engineers of Coal Producing States, blue prints and specifications showing the system adapted for utilizing waste heat from Cylinder Boilers and Blast Furnaces.



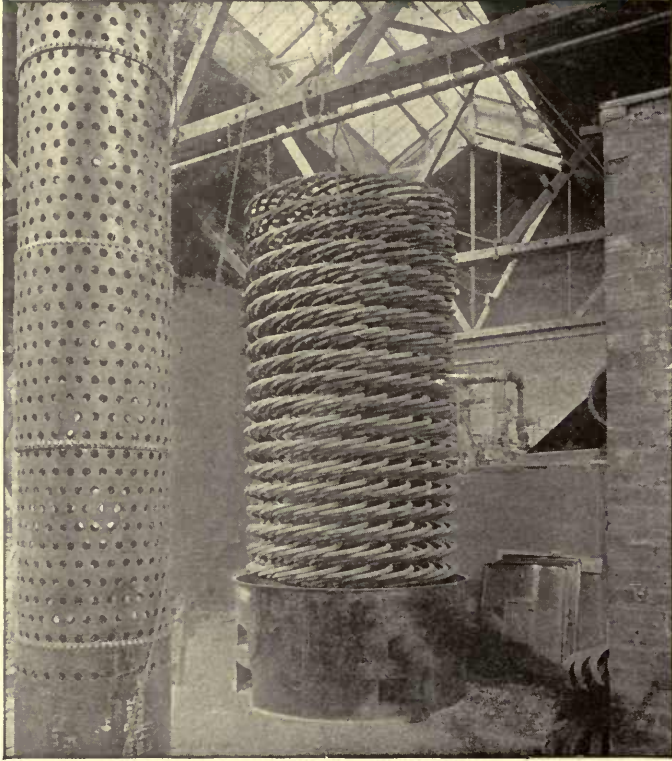
TWO 250 H. P. MORRIN "CLIMAX" BOILERS, BUILT FOR THE BRONX GAS AND ELECTRIC CO.,
WESTCHESTER, N. Y.



MUNICIPAL ELECTRIC LIGHT AND WATER WORKS STATION, NORTH ATTLEBORO, MASS.



MORRIN "CLIMAX" BOILERS AT THE WORLD'S FAIR, CHICAGO, ILL., 1893.



CLIMAX BOILERS.

IN COURSE OF ERECTION AT THE WORLD'S FAIR,
CHICAGO, ILL., 1893.

TESTIMONIALS.

The Westinghouse Electric Company.

PITTSBURGH, PA., U. S. A.,
November 27th, 1889.

THE CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

DEAR SIRs:—I have your favor of the 25th inst. The tube has arrived, and I have had it cut up, and find it in excellent condition. I note that Mr. Morrin would like to have the tube returned to you, but I would not like to part with the whole of it, and will send him a couple of pieces from it of pretty good size, if he desires the same. If you would send me the address of the parties, I will have the pieces sent from here to Wheeling, W. Va., instead of sending it to New York and back again. If this will accommodate Mr. Morrin, please send me the address.

Yours truly,

FRED'K A. SCHEFFLER,
Acting Gen'l Supt.

The Essex County Electric Company.

ORANGE, N. J., December 21st, 1889.

CLONBROCK STEAM BOILER WORKS.

DEAR SIRs:—We have been using a 200 h. p. Climax Boiler, furnished by your Works, since October 15th, and are much pleased so far with its workings. We have been taking at least 250 h. p. out of it since the middle of last month. We are particularly pleased with the dryness of steam furnished. We are also very favorably impressed with the mechanical style and workmanlike manner in which the boiler and its accompaniments were installed.

We think that this style of boiler is destined to become popular in proportion to the knowledge acquired by the public as to its peculiar merits.

Respectfully,

EDWARD E. SAGE,
President.

WM. B. BOULTON,
Vice-President.

STEWART LINDSLEY,
General Manager.

The Brush Electric Co., of Baltimore City.

BALTIMORE, August 22d, 1891.

CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

DEAR SIRs:—I have your favor of the 21st inst., relating to the test of our boiler.

I beg to state to you that we made a test of our boiler, which proved very satisfactory to the Brush Company. We evaporated 224,461 lbs. of water, and used 20,064 lbs. of slack soft coal in a test of 10 hours. The average steam pressure was $96\frac{4}{10}$ lbs.; the temperature of steam 335° ; the draft in the stack was $\frac{2}{10}$ inches; the temperature of the feed water was 152° ; the temperature of the city water was 75° . We took out from beneath the boiler 3,161 lbs. of ashes. The boiler was tested during the actual working conditions of our Station. The test was made by disinterested parties—Mr. Robert Naysmith and William Hunker, of the Allegheny County Light Company, and under the direction of the writer. I was there the entire night watching the process of the test, and can verify all the above statements as to the actual water and coal, etc., of the test. I might state that if we were to make the test over again, I have no doubt that we could evaporate much more water with the same amount of coal.

I would suggest to you that this be not made public just at present, for reasons which I will explain to you later on. I will get up a statement, if you so desire, to be made public, and will also furnish you some information relating to the Brush Electric Station of Baltimore City, to be published in any of the Electrical or Engineering papers.

I have a list of the test worked out, which was given to me by Mr. Blaxter, of the Allegheny County Light Company, which corresponds with yours, only I think he gives you a little bit more than you do yourself.

We had some difficulty in keeping the water at a certain point in the boiler during this test, but nothing serious. I am going to make some alterations in regard to water column in glass gauges, which I think will be an improvement in a general working way to the boiler.

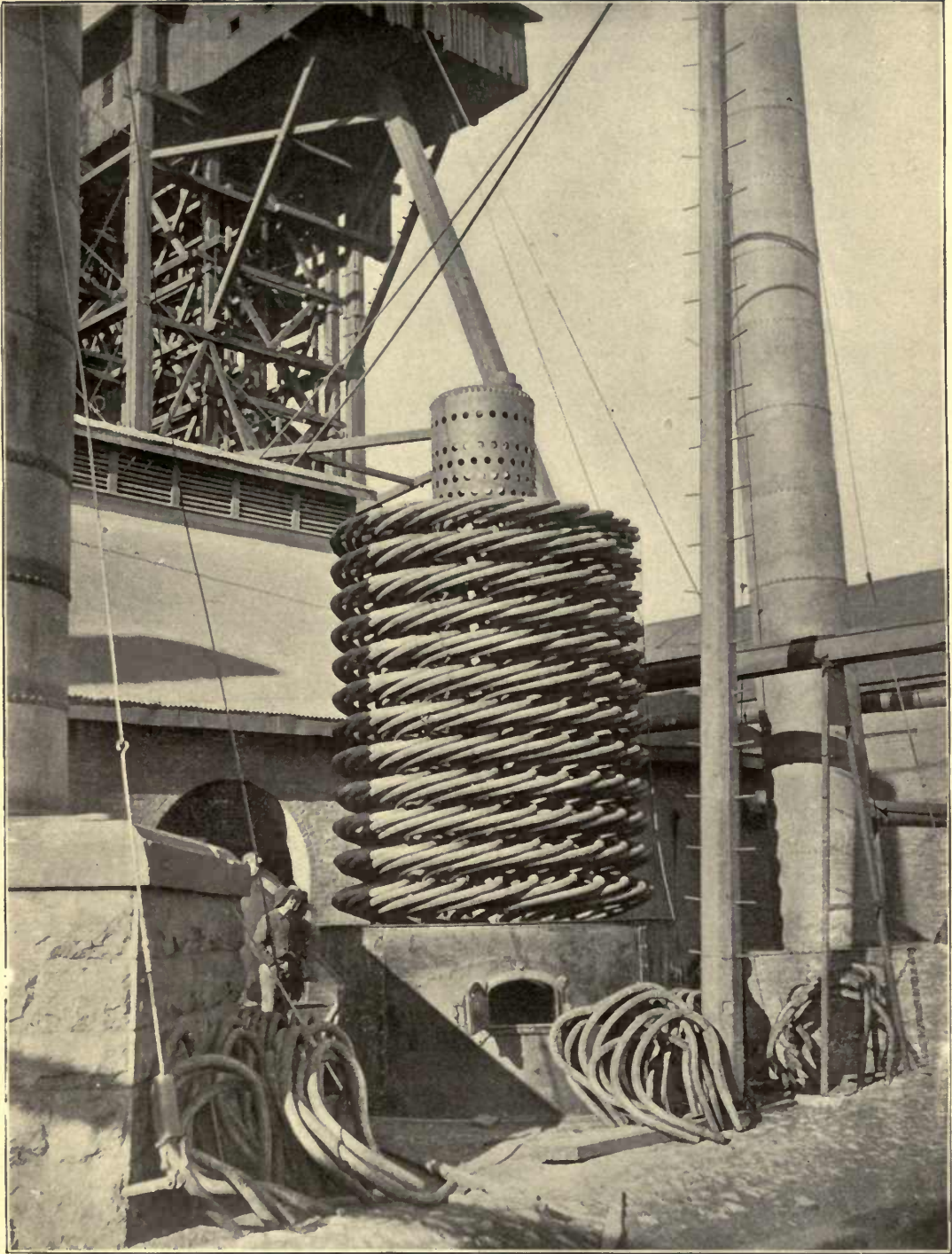
With kind regards, I remain,

Yours truly,

THE BRUSH ELECTRIC COMPANY,

E. F. BAKER,

Gen'l Supt.



VIEW OF ONE 400 H. P. MORRIN "CLIMAX" BOILER, BUILT FOR THE SUSQUEHANNA COAL CO.,
NANTICOKE, PA., 1893, AND USING WASTE HEAT FROM 12 CYLINDER BOILERS,
80 IN. DIA. X 30 FT. LONG.

The Mount Morris Electric Light Co.

NEW YORK, October 23d, 1892.

CLONBROCK STEAM BOILER WORKS,

Smith Street, Brooklyn, N. Y.

GENTLEMEN :—In reply to yours of the 22d inst., am pleased to say that the five (5) two-hundred-and-fifty (250) h. p. boilers of your make are giving very satisfactory results to us.

One of them has been running constantly for almost three years, two of them for over two years, and two for one year.

We find them very rapid steamers, and very economical on fuel.

In a recent test we made, we found that they developed from 33 to 45 per cent. above their rated capacity.

By a recent examination of one of the tubes located on the water-line, we found it to be perfectly clean and free from scale, which indicates a very rapid circulation of water.

Very respectfully,

MOUNT MORRIS ELECTRIC LIGHT CO.,

GEO. FULTON,

Chief Engineer.

EDWARD MAY,

President.

The Newark Electric Light and Power Company.

NEWARK, N. J., March 7th, 1893.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Replying to your inquiry of the 6th inst., would say that having used your boilers for nearly two (2) years without interruption, we are very much pleased with the results obtained from them. As you know, our first installation consisted of three 500 horse-power boilers, and after using these somewhat over a year, when we were in need of additional boiler capacity, we investigated at considerable length as to the actual condition of these boilers after that length of time in actual service. Having removed several of the tubes from different sections of the boiler which had the most constant use, for the purpose of examination, we found these tubes practically as clean inside as when the boilers were first started. We have since put in two more of the same size, which are working equally well. We have not made any scientific test of late to show actual results in the consumption of coal for the amount of horse-power produced, but figuring the output of this station with the total cost of our coal at same place, we find that we are running more economically than we have been able to do at any of our other stations, of which we have had three, with as many different makes of boilers. We have no hesitancy in recommending your boiler, and particularly so for our line of business.

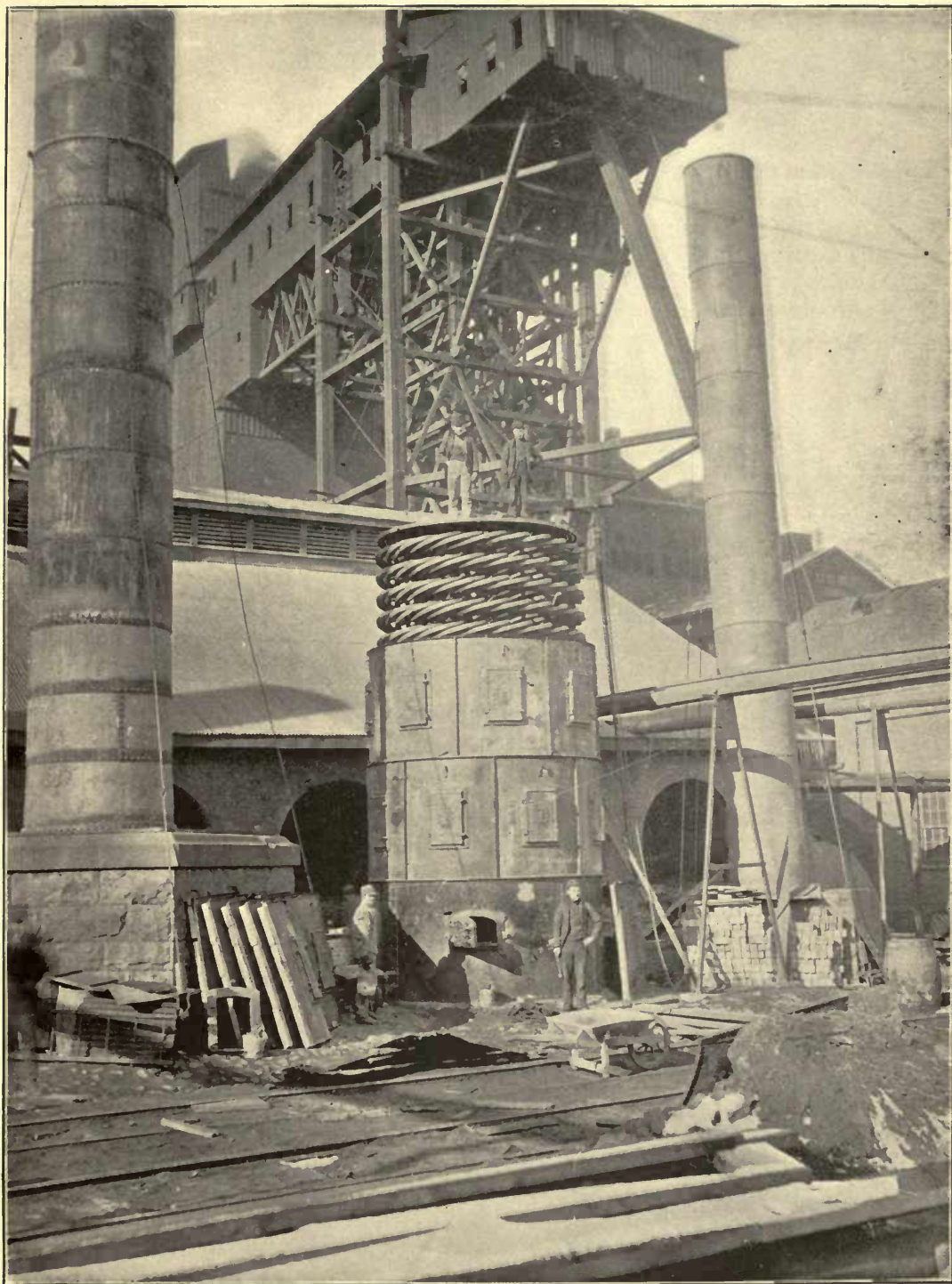
These boilers are quick steamers, and the steam obtained from same is very dry.

Wishing you every success which this boiler well merits, we beg to remain,

Yours very truly,

DUDLEY FARRAND,

Assistant Secretary.



VIEW SHOWING 400 H. P. MORRIN "CLIMAX" BOILER IN COURSE OF ERECTION FOR THE
SUSQUEHANNA COAL CO., NANTICOKE, PA.

The Manufacturers' Electric Company.

S. E. CORNER AMERICAN AND SOMERSET STREETS,

PHILADELPHIA, April 19th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN:—In reply to your inquiry respecting the 300 h. p. boiler we bought from you, as to its working, our experience with it, which has been about one year, has been very satisfactory. We have not had to replace any of the tubes and no other repairs have been required. We had it opened up a few days ago and inspected, and find it in good condition.

Comparing consumption of coal with Return Tubular Boilers we have in use, *we find it more economical, and the steam is very dry.*

Yours respectfully,

JAS. RITCHIE,

Gen'l Manager.

JERSEY CITY, April 24th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN:—In reply to your inquiry, will say that we have one of your 500 h. p. boilers in use since September last, and it is doing first class work in every way. As far as my experience goes, I think it is the best boiler made.

Yours very truly,

D. SEARLE,

Chief Engineer COLGATE & Co.

WILMINGTON, DEL., April 24th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

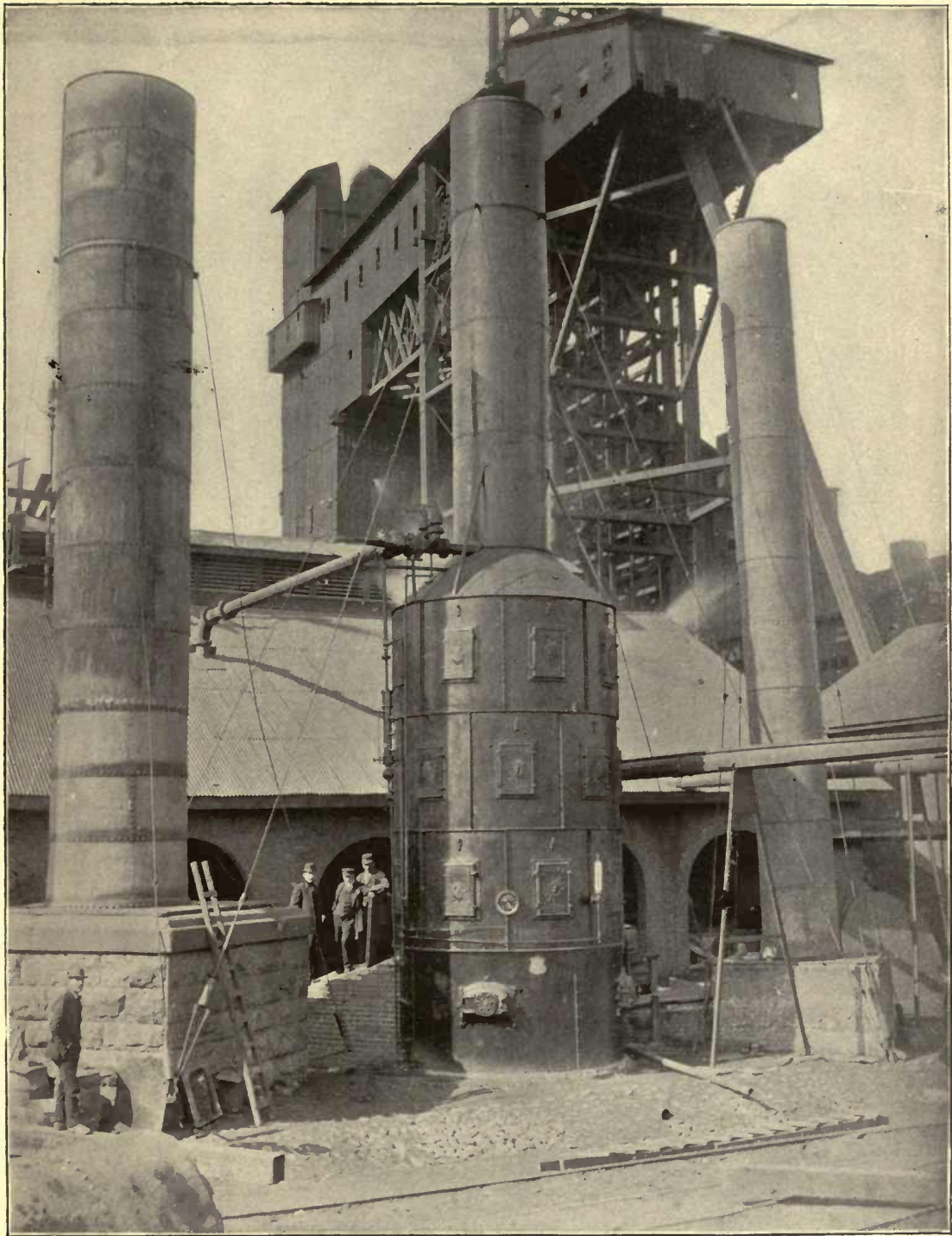
GENTLEMEN:—In reply to your request of this date as to the efficiency of the Climax Boiler, I would respectfully state that I have had charge of three of your boilers since 1886. I can cheerfully recommend them for economy, free steamers and trifling cost of repairs, giving me little or no trouble in that time, plying in both Northern and Southern waters and under all conditions. Your boiler that I am at present in charge of, after three years' service, has just stood a pressure of 400 lbs. per square inch, thereby allowing me a pressure of 200 pounds of steam. Taking it in all, I am well pleased with your boiler, the "Climax." I am much gratified to state that up to this time it has given the best possible results. I remain,

Yours respectfully,

J. G. MORAN,

Chief Engineer P. Lorillard's Yacht "Caiman."

At Wilmington, Del.



VIEW OF 400 H. P. MORRIN "CLIMAX" BOILER, COMPLETED AND READY FOR SERVICE, SHOWING FLUES
FOR CONDUCTING THE WASTE HEAT FROM CYLINDER BOILERS TO THE "CLIMAX" BOILER.
THIS BOILER DEVELOPED OVER 600 H. P.

FROM THE LABORATORY
OF
THOMAS A. EDISON.

ORANGE, N. J., February 6th, 1894.

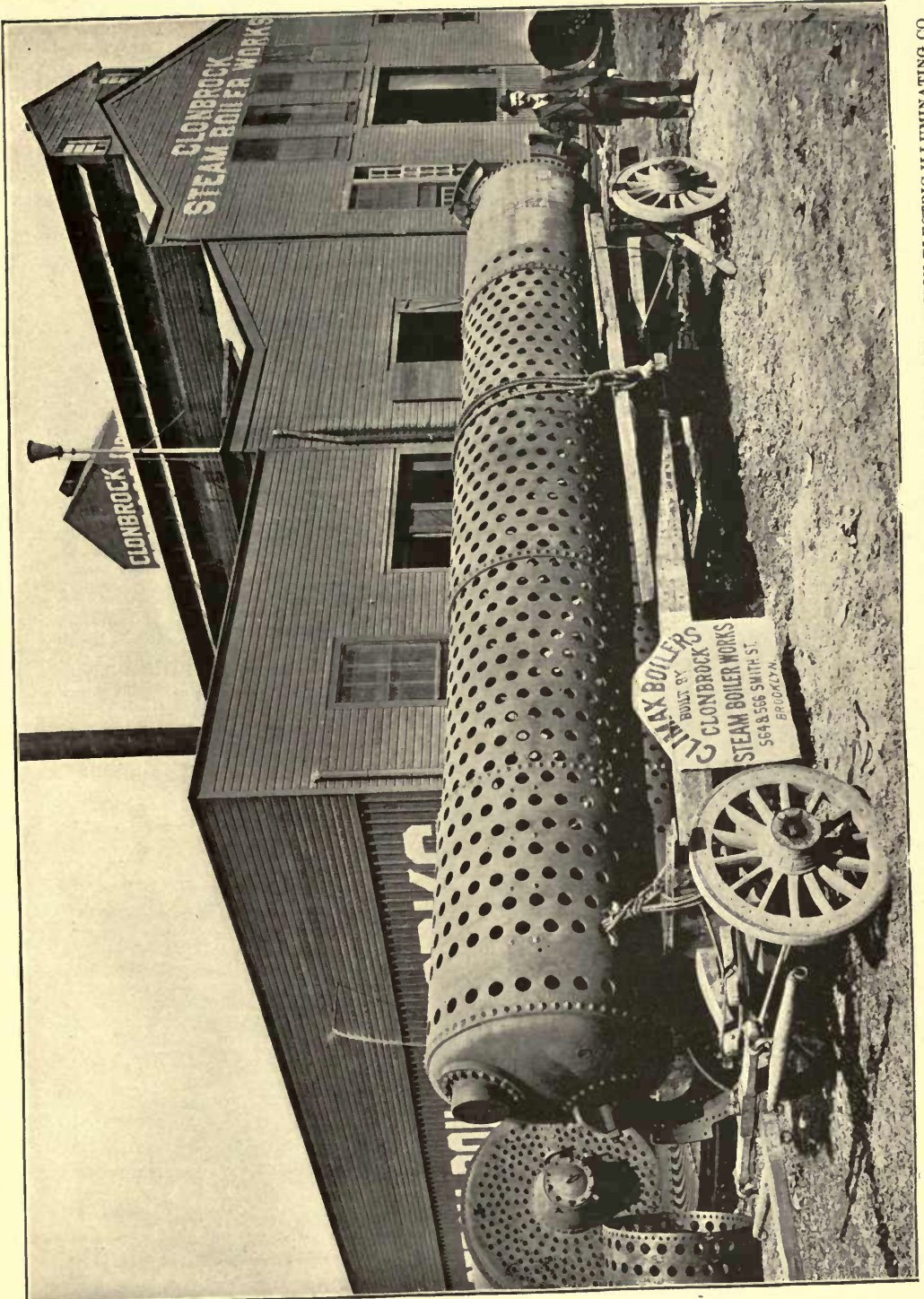
CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

DEAR SIRs:—Your letter of 30th ultimo is received. I have a Climax boiler and it is giving great satisfaction. Taking everything in consideration it is, in my opinion, practically and theoretically, the best boiler so far invented.

Yours truly,

THOMAS A. EDISON.



600 H. P. MORRIN "CLIMAX" BOILER SHELL, LOADED ON TRUCK AND READY FOR SHIPMENT. BUILT FOR THE EDISON ELECTRIC ILLUMINATING CO.,
BROOKLYN, N. Y., PEARL STREET STATION.

Chicago Edison Company.

CHICAGO, April 20th, 1894.

CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

GENTLEMEN :—In reply to your inquiry as to our experience and opinion of the "Climax" Boiler, will say that the first of these that we purchased was installed and fired in November of 1892. This boiler is rated at 500 h. p., and has been doing considerably more than that amount of work since that date.

We installed a second similar boiler a year later; and two more are being erected at the present time.

We have found these boilers to be extremely quick steamers, to be capable of generating considerably more than their rated capacity, to be very economical in the matter of fuel, and, so far, to require practically no repairs.

We are extremely well pleased with them.

Yours truly,

C. H. WILMORING,
Gen'l Supt.

Edison Electric Illuminating Company of Brooklyn.

BROOKLYN, April 23rd, 1894.

CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

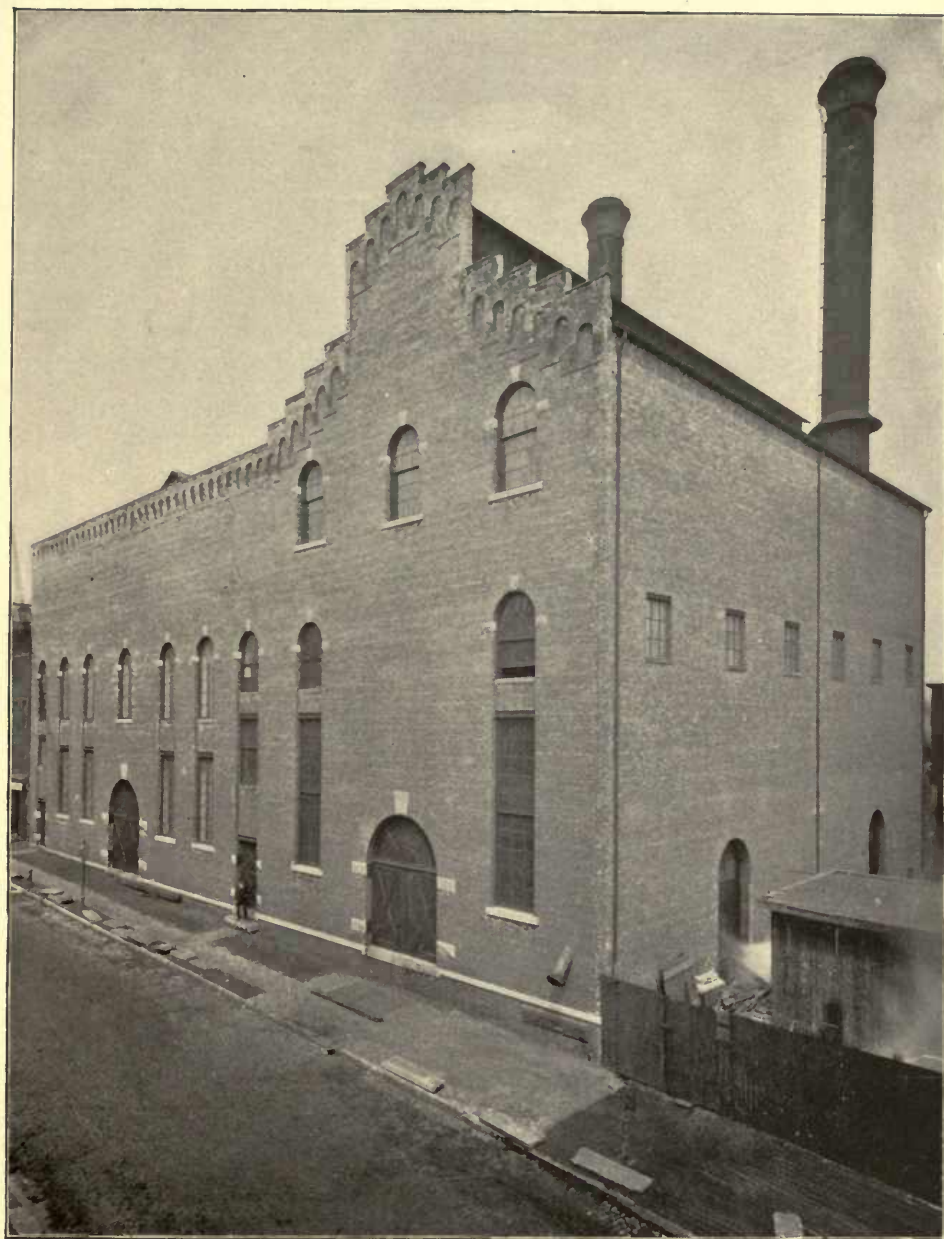
GENTLEMEN :—In reply to your favor of April 16th, in regard to our opinion of the Climax Boilers, I would say that we have experienced nothing but the most genuine satisfaction since their introduction. We, as you know, first used the boiler in connection with our Third District station, and have had them in continual use for the past eighteen months, the pressure ranging from 160 to 200 pounds. We find that the boilers carry out in actual practice all the theoretical claims made for them, and not only have they proved most efficient and reliable, but since starting have cost us nothing for repairs.

After a trial of a year in this station, we adopted them in our Second District plant, where they have been in use for about eight months. We are now erecting two in our Buffalo Bill "Wild West" annex station, and are already making plans to install 3,600 h. p. of them in our First District, Pearl Street plant. The boilers have shown no tendency to scale, and I do not anticipate any trouble in this direction.

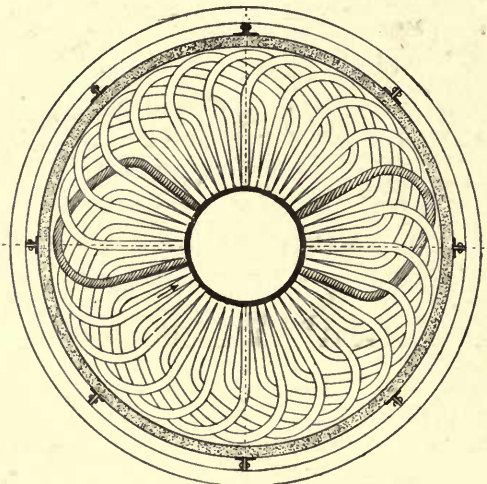
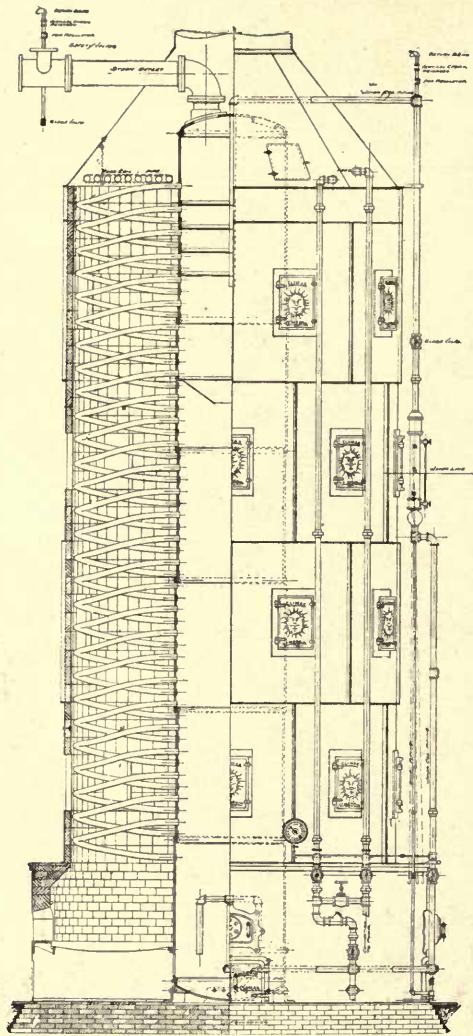
Trusting your boilers will meet with the same success in other stations, I remain,

Yours truly,

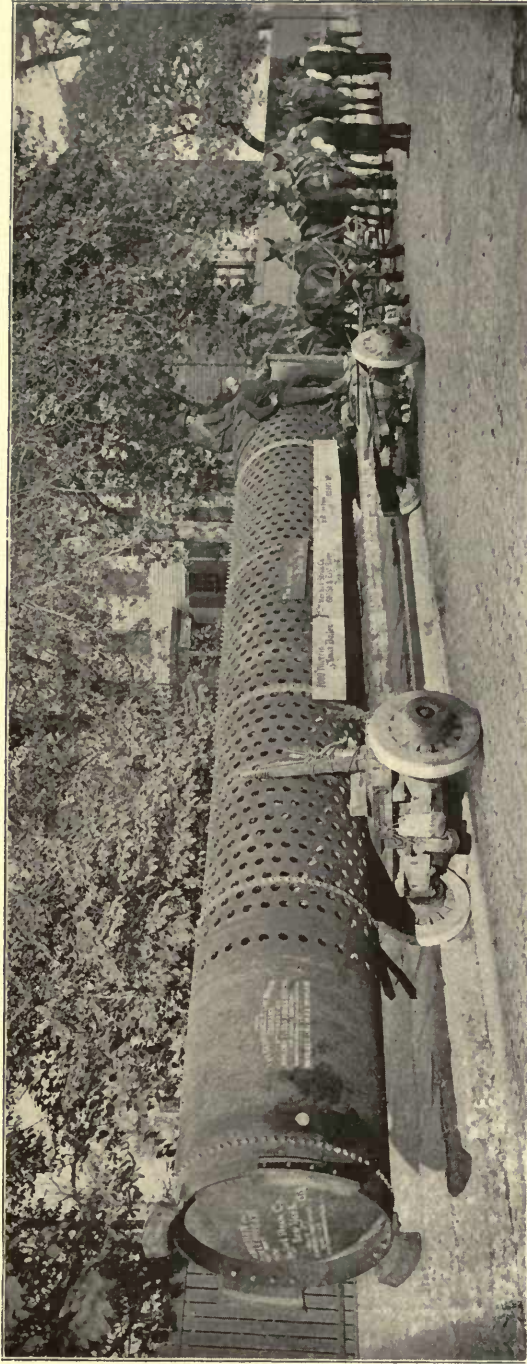
W. S. BARSTOW,
Gen'l Supt.



POWER STATION OF THE UNITED ELECTRIC LIGHT AND POWER CO., EAST 29TH ST., N. Y. CITY.
THIS PLANT CONTAINS SEVEN 600 H. P. AND TWO 500 H. P. MORRIN "CLIMAX" BOILERS.
WHEN COMPLETED WILL CONTAIN THIRTEEN 600 H. P. AND TWO 500 H. P.
MORRIN "CLIMAX" BOILERS.



1,000 H. P. MORRIN "CLIMAX" BOILER FOR THE EAST 60TH ST. STATION
OF THE NEW YORK STEAM CO., NEW YORK CITY.



1,000 H. P. MORRIN "CLIMAX" BOILER FOR THE EAST 60TH ST. STATION OF THE NEW YORK STEAM CO., NEW YORK CITY.
THIS PLANT WILL CONTAIN 20,000 H. P. WHEN FINISHED.

Coney Island & Brooklyn R. R. Co.

SMITH AND NINTH STREETS,

BROOKLYN, Dec. 18th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Replying to yours of the 30th ult., we installed two (2) Climax Boilers of 350 h. p. each in July, 1892, and one (1) in May, 1893.

The said Climax Boilers have been in active service night and day since. They have never cost us one cent for repairs, and I do not hesitate to recommend them. I expect to have a copy of tests made by Columbia College within a day or so when I will be pleased to send you a copy of same.

H. M. NASH, *Chief Engineer*,
Coney Island & Brooklyn R. R. Co.

The Colonial Company, Limited.

TRINIDAD, Jan. 7th, 1895

To the Directors of

THE CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—In reply to your memorandum of the 11th ultimo, asking for an expression of opinion as to the merits of the "Climax" Boiler as applied to sugar house work, we may state that two of these boilers of 600 horse power each have now run through two campaigns at the Usine Ste. Madeleine.

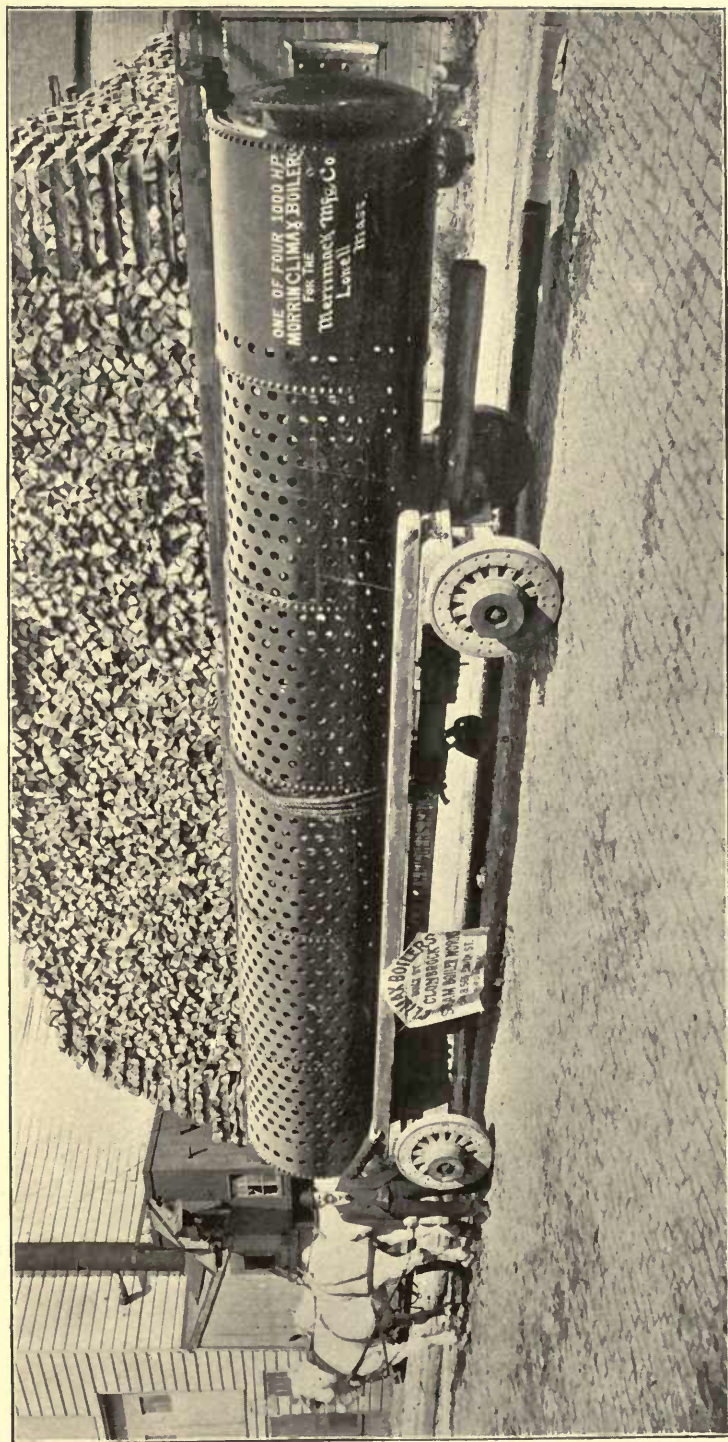
Last year two more of 1,000 horse power each were erected, and we understand from our Manager that the installation has given great satisfaction.

We are, gentlemen,

Yours truly,

THE COLONIAL COMPANY, Limited.

per ANDRE BERNARD.



1,000 H. P. MORRIN "CLIMAX" BOILER FOR THE MERRIMACK MFG. CO., LOWELL, MASS.

Merrimack Manufacturing Co.

LOWELL, MASS., May 22d, 1896.

MR. GEO. P. FLINN,

Boston, Mass.

DEAR SIR:—Yours of the 21st at hand and contents noted. In looking over the test of the No. 7 1,000 horse power "Climax" Boiler, I find that the average actual evaporation corrected for moisture from and at 212 degrees is

12.79 the 1st test, lbs. of water per lb. combustible.

12.44 " 2d " " " "

12.37 " 3d " " " "

CORRECTED FOR SUPER-HEAT AND MOISTURE IT IS

13.16 lbs. of water per lb. combustible on 1st test.

12.54 " " " " 2d "

12.80 " " " " 3d "

THE PERCENTAGES OF SUPER-HEAT ARE AS FOLLOWS:

5.30% on the 1st test.

8.90% " 2d "

6.77% " 3d "

THE MAXIMUM DEGREES OF SUPER-HEAT WERE AS FOLLOWS:

37° on the 1st test for one hour.

49° " 2d " "

44° " 3d " "

Coal used, George's Creek, fired by Wilkinson stokers; this speaks well for the boiler. Our readings were taken every fifteen minutes, and coal and water weighed on the scales.

The draft on the 1st test was .755"

" " 2d " .738"

" " 3d " 1.25"

Average temperature feed water, 1st test, 45.2°

" " " 2d " 46.8°

" " " 3d " 33.5°

Hoping that this may interest you, I am,

Yours truly,

(Signed) D. J. LEWIS, JR.,

Chief Engineer.



TREMONT BUILDING, BOSTON, MASS.

EQUIPPED WITH FOUR 150 H. P. MORRIS "CLIMAX" BOILERS.

Buchanan & Lyall Tobacco Factory.

346 CARROLL ST.,

BROOKLYN, N. Y., Nov. 8th, 1894.

CLONBROCK STEAM BOILER WORKS,

Smith St., Brooklyn, N. Y.

GENTLEMEN :—Your letter of the 23rd October was handed me to reply to. Regarding the celebrated Morrin Climax Steam Generator, I would say that we have had a 250 h. p. boiler in constant use night and day for three years, and under my care for nearly a year.

I am free to say that it is all that you represent it to be. It is a great Steam Generator. We open it up once a month, and find it to be as clean as a whistle, which proves that the circulation of water must be good, if not perfect.

I consider the boiler second to none, and should we ever need another boiler, I am prepared to advise the putting in of a Climax.

I remain,

Yours very truly,

WM. K. AUSTIN, *Engineer*,

At Buchanan & Lyall Tobacco Factory.

The Central Railway and Electric Co.

NEW BRITAIN, CONN., Dec. 1st, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Answering yours of October 23rd, will say that we have two 500 h. p. Climax Boilers that have cost us very little expense for repairs, and have given us good satisfaction. When we make another increase we expect to do it with the same style of boiler.

Yours truly,

E. S. BREED, *Supt.*

The New York Biscuit Company.

TENTH AVENUE, FIFTEENTH AND SIXTEENTH STREETS,

NEW YORK, Dec. 5th, 1894.

CLONBROCK STEAM BOILER WORKS,

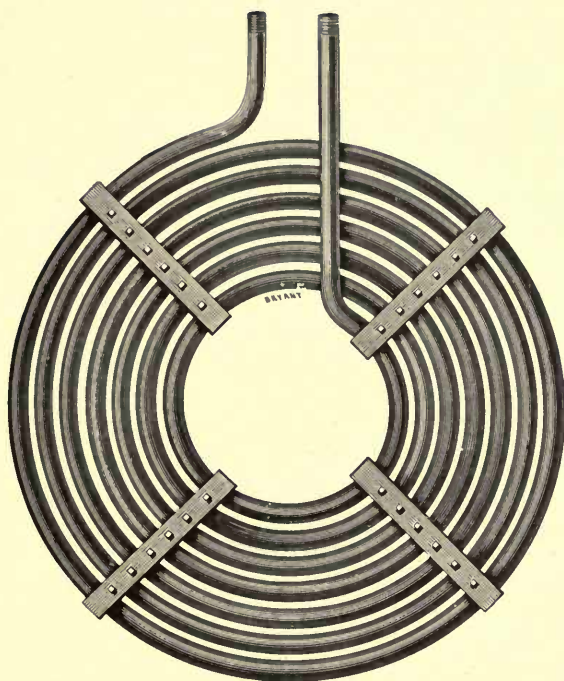
Brooklyn, N. Y.

GENTLEMEN :—Replying to your esteemed favor of the 30th ultimo, we take pleasure in stating that we have used your "Climax" boilers continuously for three years and found them good steamers, and satisfactory in all respects.

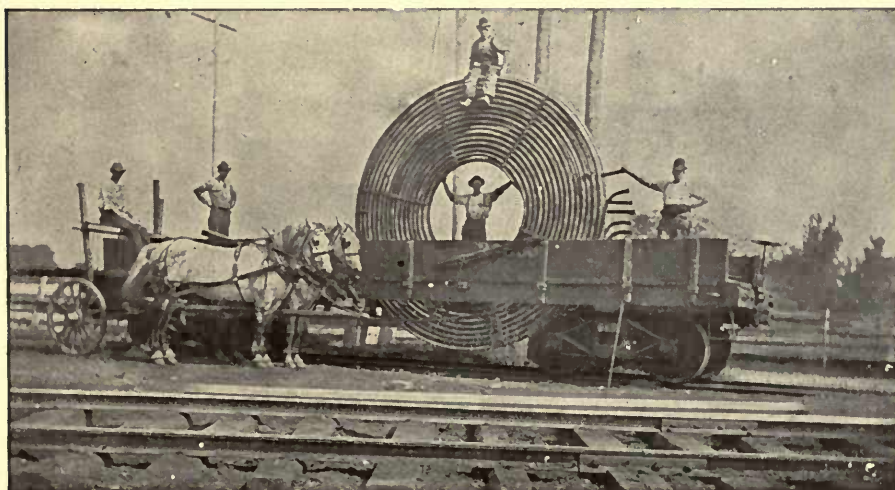
Very truly yours,

THE NEW YORK BISCUIT CO.,

per JOS. LAMER.



FEED WATER HEATER FOR MORRIN "CLIMAX" BOILER.
E. H. IRON PIPE.



SHIPMENT OF FEED WATER HEATERS FOR MORRIN "CLIMAX" BOILERS
AT THE WORLD'S FAIR, CHICAGO, ILL., 1893.

New York Dredging Company.

WORLD BUILDING,

NEW YORK, April 30th, 1894.

CLONBROCK STEAM BOILER WORKS,

564 Smith Street, South Brooklyn, N. Y.

GENTLEMEN :—In January, 1893, we installed on our dredge boat "Florida" a 400 horse power "Climax" boiler of your manufacture, since which time it has been in constant use night and day, and it gives us pleasure to say that on the whole it has been satisfactory.

We remain,

Yours truly,

NEW YORK DREDGING CO.

By GEO. W. CATT, *Pres.*

Thomson-Houston Electric Co. of New York.

425 EAST 24TH STREET.

H. W. GRAY, *Receiver.*

NEW YORK, Oct. 26th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Our experience with the "Climax" Steam Generator is that we cannot find its equal in efficiency, handiness and general results in the market.

Very respectfully yours,

THOMSON-HOUSTON EL. CO. OF N. Y.

P. E. LEAHY, *Chief Eng. and Supt.*

Mt. Jessup Coal Company, Limited.

ELI T. CONNER, *Supt.*

WINTON, PA., Nov. 7th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Your favor of the 27th October received. In reply, will say that the 300 h. p. "Climax" Boiler we purchased from you has enabled us to dispense with the use of five Cylinder Boilers, and to make more steam than formerly. The "Climax" takes waste gases of eight Cylinder Boilers and steams fully up to rated capacity, and we think with a few changes in grate bars and blowers will exceed that horse power. The boiler has been in use about four months, and so far has given entire satisfaction.

Very truly yours,

ELI T. CONNER, *Supt.*

Colgate & Company,

53 & 55 JOHN ST.,

NEW YORK, Dec. 6th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

DEAR SIRs :—Your favor of Nov. 30th is at hand. We take pleasure in stating that the 500 h. p. Climax Boiler, which you placed at our works about a year ago, has proved satisfactory to us in every respect, and has accomplished all that you stated it would.

We have already recommended it to several parties as being one of the best boilers with which we are acquainted.

Yours very truly,

COLGATE & Co.

F. W. Wurster & Co.

Rolling Mill, Spring and Axle Works.

BROOKLYN, Dec. 12th, 1894.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—In reply to yours of the 12th inst., we are pleased to say that after using your Climax Boiler for the past three years that it has given entire satisfaction. As used in connection with our heating furnaces, we have been able to run one 500 h. p. engine from the surplus heat without the use of coal under the boiler. We also find that it consumes most of the smoke that comes from using soft coal in the furnaces.

The only expense that we have had in the three years that we have used the boiler has been for new fire brick.

Yours respectfully,

F. W. WURSTER & Co.

Baltimore Traction Company.

BALTIMORE, MD., Dec. 17th, 1894.

CLONBROCK STEAM BOILER WORKS,

29 Broadway, New York City.

GENTLEMEN :—We have ordered Climax Boilers four times on account of our own experience with them. Some in use two years. No leaky tubes. They are doing their work admirably.

Yours truly,

BALTIMORE TRACTION Co.,

F. H. HAMBLETON, C. E.

Brooklyn City and Newtown Railroad Co.

BROOKLYN, N. Y., January 5th, 1894.

CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

GENTLEMEN :—In answer to the inquiries from your firm, we beg to say that on December 3d, 1892, we commenced operating the first of the four boilers erected under our original order.

We have been very well satisfied with the results attained, so much so that on October 3d last, we ordered a fifth boiler similar to the first four, our business having increased so that we required more power.

Yours very truly,

JOHN N. PARTRIDGE,

President.

D. H. Burnham, Director of Works, World's Columbia Exposition.

JACKSON PARK, CHICAGO, November 18th, 1893.

THE CLONBROCK BOILER WORKS,
Brooklyn, N. Y.

GENTLEMEN :—It gives me pleasure to state that your boilers in the Power Plant of the World's Columbian Exposition have given exceedingly good satisfaction, and have always responded promptly to any call made upon them.

Yours very truly,

GEO. ROSS GREEN,

2d Asst. Mechanical Engineer.

Supt. Boiler Plant.

American Ring Company.

WATERBURY, CONN., April 17th, 1894.

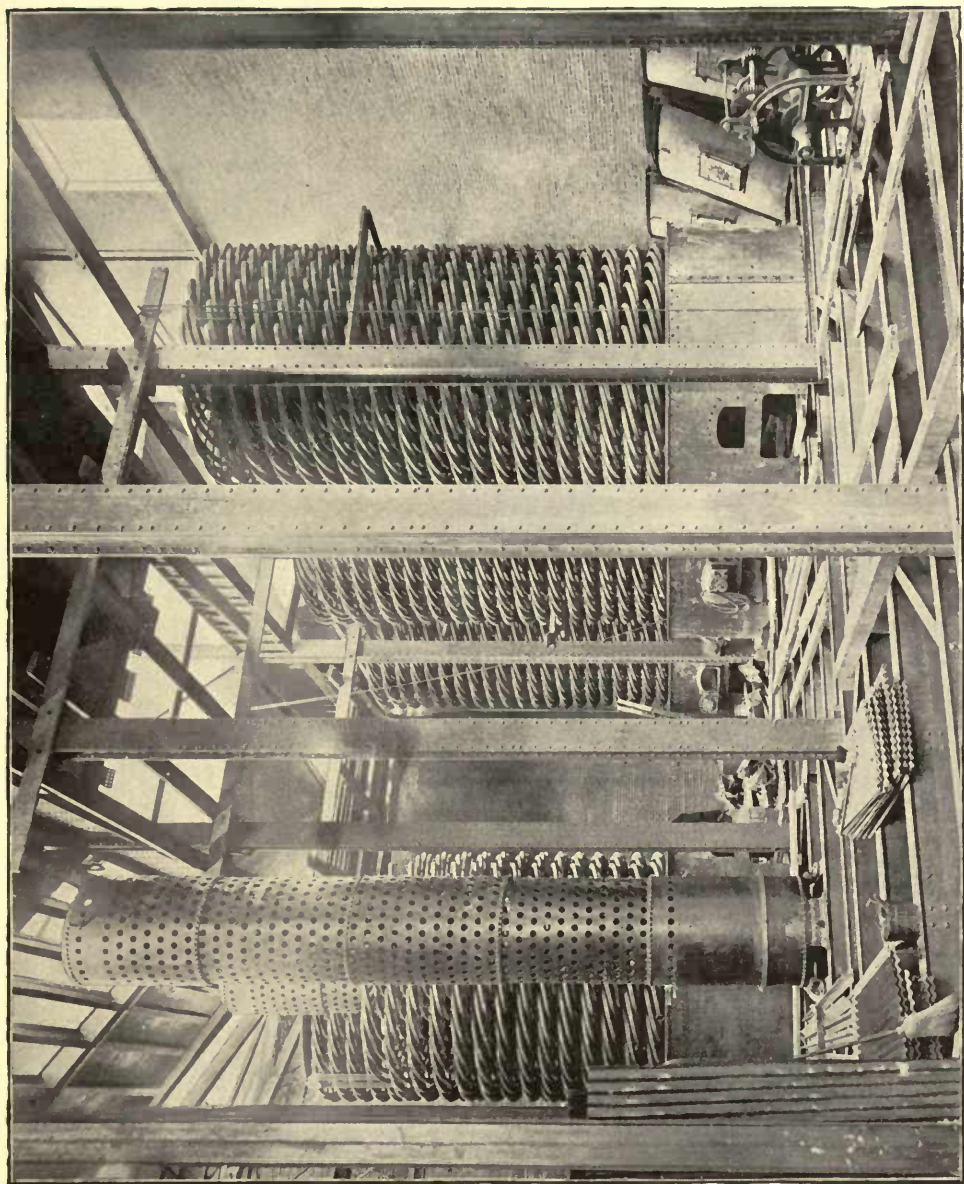
CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

GENTLEMEN :—In reply to yours of the 14th, would say that we have had your Climax Boiler in use nearly two years, and it has given us the utmost satisfaction. We consider it an economical boiler, and it most certainly is a rapid steam maker. We can get pressure up to 80 lbs. on the Climax Boiler in less than half the time it takes to get up a pressure on our Horizontal Boilers. When we first put in your Climax Boiler we were using water that had a good deal of lime in it, *and scale formed in our Horizontal Boilers to a very considerable extent, whereas in the Climax Boilers there was almost no deposit of scale, and we attributed the difference to the rapid circulation of water through the tubes of the Climax Boiler.*

Yours truly,

AMERICAN RING Co.,

D. N. PLUME, *Sec'y.*



SIX 600 H. P. MORRIN "CLIMAX" BOILERS BEING ERECTED FOR THE UNITED ELECTRIC LIGHT AND POWER CO.,
EAST 29TH STREET, NEW YORK CITY.

Riverside Iron Works.

September 20th, 1895.

COLCHESTER RUBBER CO.,

Colchester, Ct.

GENTLEMEN:—We duly received your favor of the 14th inst., and referred same for report to the Superintendent of our Steel Department, who has special charge of the "Climax" boiler that we have in use. He reports as follows:

"Riverside Iron Works have five Morrin 'Climax' Boilers in use, the oldest one having been in use five years and some months. During that period we have replaced in the five boilers, containing 2375 tubes, about 100 tubes. As you may be aware the water used here is very bad, and we have forced the boilers very hard. We regard this an excellent report, and far better than results we are obtaining from our old Cylinder Boilers. The tubes are readily replaced, the work being done by our own boiler house men, and no boiler-maker has done an hour's work on the 'Climax' Boilers since they were started. The expense of repairs on our Horizontal Tube Boilers has been very much in excess of the cost of repairs on the 'Climax.' This Company is now installing three more of the 'Climax' Boilers in the different departments of their works."

We trust the information given will be of service to you, and awaiting your further advice, we are,

Yours truly,

RIVERSIDE IRON WORKS.

The L. Candee & Co.

NEW HAVEN, CONN., May 19th, 1896.

E. LYMAN, ESQ.,

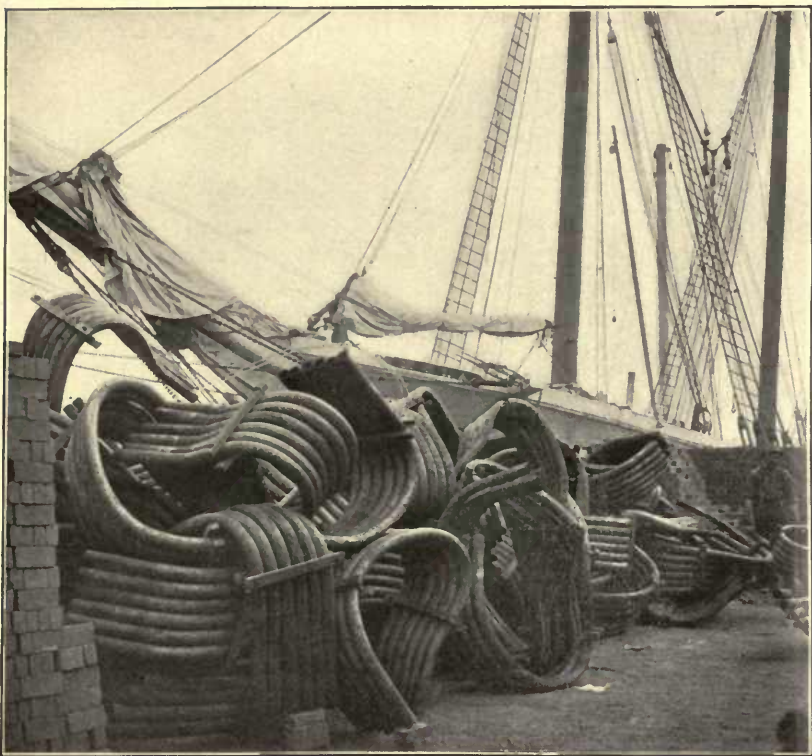
DEAR SIR:—Your letter has been mislaid, and just been found to-day. We have an 800 horse power Morrin "Climax" Boiler. This boiler has proved very satisfactory to us. We do not contemplate putting in more at present, as this furnishes us all the power which we need at present.

We have used this boiler since last November, and we get a very dry steam from it. In regard to the power which we get from it, would say that we have been getting double what it is rated at. Our engineer speaks very highly of this boiler.

Yours very truly,

(Signed) C. G. AMES,

Superintendent.



SHIPMENT OF TWO 350 H. P. MORRIN "CLIMAX" BOILERS FOR THE CENTRAL ANSONIA SUGAR PLANTATION, AZUA, CUBA, 1894.

Usine Ste. Madeleine.

TRINIDAD, W. I., January 27th, 1893.

CLONBROCK BOILER WORKS,
Brooklyn, N. Y.

DEAR SIRs:—The boilers have been at work for over a week and I am glad to say are doing very well.

The feed pipe is, however, found to be too small. Before the specification was completed, you will remember, I pointed out that this would be the case, and I would therefore ask if you cannot see your way to supply a set of 3-inch feed and retaining valves for each boiler.

Possibly you would, under the circumstances, also supply 3-inch coils, which we could let in when opportunity occurred.

I am, dear sir,

Yours faithfully,

P. ABEL.

Usine Ste. Madeleine.

TRINIDAD, W. I., February 11th, 1893.

CLONBROCK BOILER WORKS,
Brooklyn, N. Y.

DEAR SIRs:—I confirm my letter of January 27th, and now beg to enclose a memorandum (No. 33, dated February 10th,) on the lines indicated, in which I would be glad if you would kindly furnish, per return of S. S. "Burnley" or other early opportunity, a specification of a Climax Boiler of 1,000 h. p.

I may mention that the boilers had from you in August last have now been at work several weeks and are giving great satisfaction.

I send copy of this to Mr. Fogarty, and now enclose you a copy of what I am writing him.

I am, dear sir,

Yours faithfully,

PETER ABEL.

Coney Island and Brooklyn R. R. Co.

BROOKLYN, N. Y., January 31st, 1893.

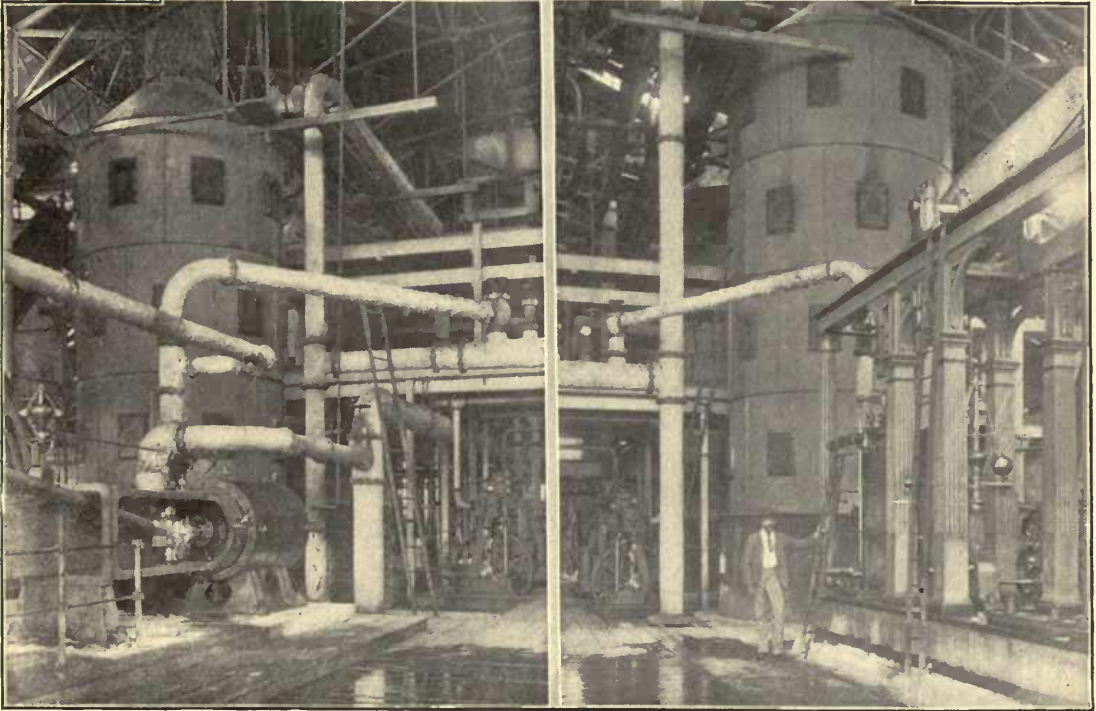
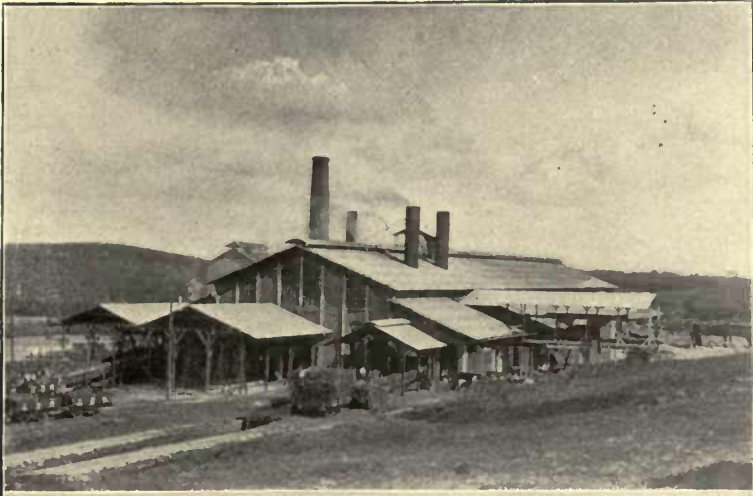
DEAR SIRs:—In reply to yours of 28th inst., I am instructed by the President of our Company, General H. W. Slocum, to say that the officers, without exception, unite with him in expressions of entire satisfaction with the boiler work done by your firm for this Company, and known as the Clonbrock Steam Boiler Works.

Very respectfully,

ED. F. DRAYTON,

Sec. and Treas.,

CONEY ISLAND & BROOKLYN R. R. Co.



BOILER ROOM OF THE "USINE STE. MADELEINE" SUGAR PLANTATION, TRINIDAD, B. W. I.,
CONTAINING TWO 1,000 H. P. AND TWO 600 H. P. MORRIS "CLIMAX"
BOILERS, USING BEGASSE FUEL.

Usine Ste. Madeleine.

TRINIDAD, W. I., March 6th, 1894.

CLONBROCK BOILER WORKS,

Brooklyn, N. Y.

DEAR SIRs:—You must have expected long ere this to hear something about the boilers and I must express regret at the disappointment. We have been so occupied starting other new things that writing has been next to impossible.

I need hardly say the boilers are doing magnificent work. We have not yet been able to make any tests of their evaporation capacity, but it must be very great.

The furnaces are worked—the pair of 600 horse power boilers, with double crusher megass, the pair of 1,000 horse power with single crusher, the descending flue in the latter case being eight feet longer than the other, of which I sent Mr. Fogarty the drawing.

The mean of the analysis of flue gases up to date is given you on the enclosed certificate by the chemist of the establishment.

Mr. Scurd, of Demerara, and I expect to be in New York, via Cuba, early in May. We shall be glad to say a word in favor of the boilers in Cuba, and if you could send us a line of introduction to any of your friends there it might facilitate matters.

We shall go to the Hotel Pasaje, but meanwhile you might send me a line to Central de Canovanas, San Juan, Porto Rico, where we expect to be up to the middle of April.

From Porto Rico, the Marquis de las Claras writes me enquiring about the boilers, furnaces, etc. I shall see him when we get there; meanwhile I have told him I shall bring him all the particulars about setting and furnace that he requires.

With kind regards, I am,

Faithfully yours,

P. ABEL.

U. S. M.

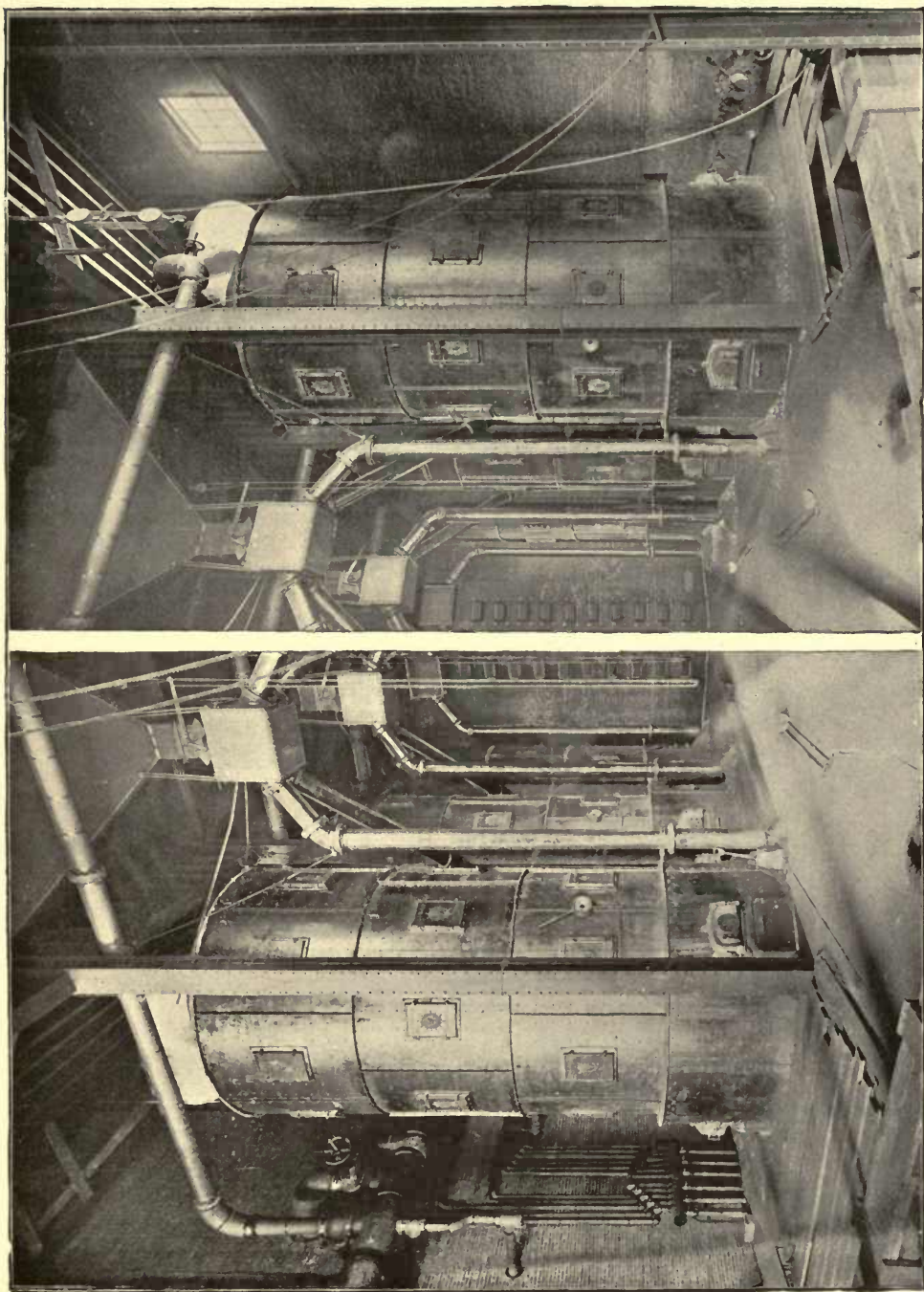
Average composition of flue gases burning producer gas to date.

C O ₂	O.	C. O.	N.	Multiple of theo. rest G.	Temp. at Dome.	Draught ft. per second.
10.8	8.7	0.3	80.2	1.74	440	28.0

W. J. FULTON,

March 6th, 1894.

Chemist.



COMPLETED VIEW OF SIX 600 H. P. MORRIN "CLIMAX" BOILERS AT THE STATION OF THE
UNITED ELECTRIC LIGHT AND POWER CO., EAST 29TH ST., N. Y. CITY.

The Colonial Company, Limited.

LONDON, E. C., April 29th, 1893.

MESSRS. THE CLONBROCK STEAM BOILER WORKS,
South Brooklyn, N. Y.

DEAR SIRs:—We have to thank you for your letter of 11th inst., and in accordance with your suggestion we, on 27th inst., telegraphed you the word “Yes,” meaning that we had determined to order for our Usine Ste. Madeleine in Trinidad, two more Climax Boilers of 1,000 American h. p. each, and wished you to proceed at once to order the material and get the work under way, which we now confirm.

We expect Mr. P. Abel, Manager of said Usine, will shortly be in New York, and as we are anxious that he should be free to arrange with you with regard to any details of construction and fitting, we are sending to him one copy of your estimate, signed by us under the following condition :

“We confirm the above contract subject to any alterations which may be agreed upon between yourselves and Mr. P. Abel, of Trinidad.”

In consequence of these boilers not being fired with coal, there are some small items which would in the ordinary course be included in the price given, such as grate bars, which we shall not require, and as to which we think you might make us some little allowance, but we must leave this to be arranged between yourselves and Mr. Abel.

We are, dear sirs,

Yours faithfully,

THE COLONIAL COMPANY, Limited.

J. WEEFORD,

Managing Director.

The World's Fair, Jackson Park.

CHICAGO, July 8th, 1893.

MR. F. SARGENT,
Chicago, Ill.

MY DEAR SIR:—Mr. Jones, of the Climax Boilers, tells me that a mutual acquaintance has been to you and spoken disparagingly of the Climax Boilers, or their burners, etc., now at the World's Fair, and given me as authority. I wish to state emphatically that I have not had anything but the highest opinion of this boiler and the burners. The 500 h. p. boiler has been developing a large percentage above its rating, and as a steamer it would be hard to surpass.

Yours very truly,

GEO. ROSS GREEN.

The Edison Electric Illuminating Co.

EASTON, PA., February 1st, 1893.

THE CLONBROCK STEAM BOILER CO.

GENTLEMEN:—The Board of Directors at a meeting yesterday decided to put in another 600 h. p. boiler of your make. Before giving you the order for same, I desire to advise with Mr. Vail as to some details in connection with it.

The fact that we are increasing our steam capacity, and adding another of your type of boiler, is evidence that the type of boiler has given us entire satisfaction. We have been doing much work with it, and that in view of the fact that the boiler *has not been cleaned for over a year.*

Yours respectfully,

(Dictated.)

HOWARD RINEK.

Edison General Electric Company.

NEW YORK, January 31st, 1893.

THE CLONBROCK STEAM BOILER WORKS,

564 Smith St., Brooklyn, N. Y.

DEAR SIR:—As we have just opened one of our 1,000 h. p. Climax Boilers in the Cincinnati Station, after a continuous run of over two months, I beg to say that I am more than pleased with the report of Engineer Turner on the same. Although we are using the condensed water from the engines through the boilers over and over again, which makes it naturally liable to deposit more or less grease in the boilers, I take pleasure in informing you that it showed no signs of any such deposit. There was but very little dirt in the mud-pit of the boiler (if I may thus call it,) due principally to the falling off of the mill scale; the tubes were absolutely clean, and the boiler has never leaked a drop since started, which I may say is the same with the other two boilers belonging to the battery. The three boilers have now been in operation for a year, and show no sign of either wear or destructive action from gases outside or the use of the re-condensed water internally. The only trouble we did have was in placing the water-line too high, which was excusable with such a new and large-sized boiler, and since the water-line is lowered we have no possible fault to find with them. As a rapid steam-producer, for electric plants—either lighting or railway—so as to take care of any sudden load that may be called for, I do not know any type of boiler to equal it. The ease of access in cleaning is another great point in its favor, which can be readily seen from the above-mentioned boilers being constantly under steam for over two months. Another point is the want of bricks in its construction, thus doing away with a large expense for renewals and repairs. In a single story-station its small floor space makes it very valuable, as the horse-power can be more than quadrupled per foot of floor by using it. I understand that Mr. T. A. Edison, after looking closely into it, thinks that there is no boiler like it. I am highly satisfied with them not only in Cincinnati, but at all other locations you have installed them for us.

Yours respectfully,

J. C. HENDERSON,

Engineer-in-Chief.

The Cincinnati Edison Electric Company.

CINCINNATI, February 4th, 1893.

THE CLONBROCK BOILER WORKS,
Brooklyn, N. Y.

GENILEMEN :—In regard to your inquiry as to the operation and efficiency of the three boilers now in use in this Station, I beg to state that these boilers have been in use since November 4th, 1891, and since that time have given perfect satisfaction. They are easy to steam, are economical with fuel, and I have never found any trouble about keeping the tubes clean. We run the boilers about four weeks before cleaning them, running day and night, and never find any dirt of any account in the tubes. They have never cost us anything for repairs since we have started, and I think, with ordinary care, the repairs of these boilers will be very light.

Very truly yours,

JOHN TURNER,

Superintendent and Engineer.

Chicago Arc-Light and Power Company.

CHICAGO, February 18th, 1893.

CLONBROCK STEAM BOILER WORKS,
No. 29 Broadway, New York City.

DEAR SIRs :—I wrote you a few days ago stating that we were holding payment on your account for the returns from a test on the boiler. We found the results very satisfactory and mailed you check a day or two ago.

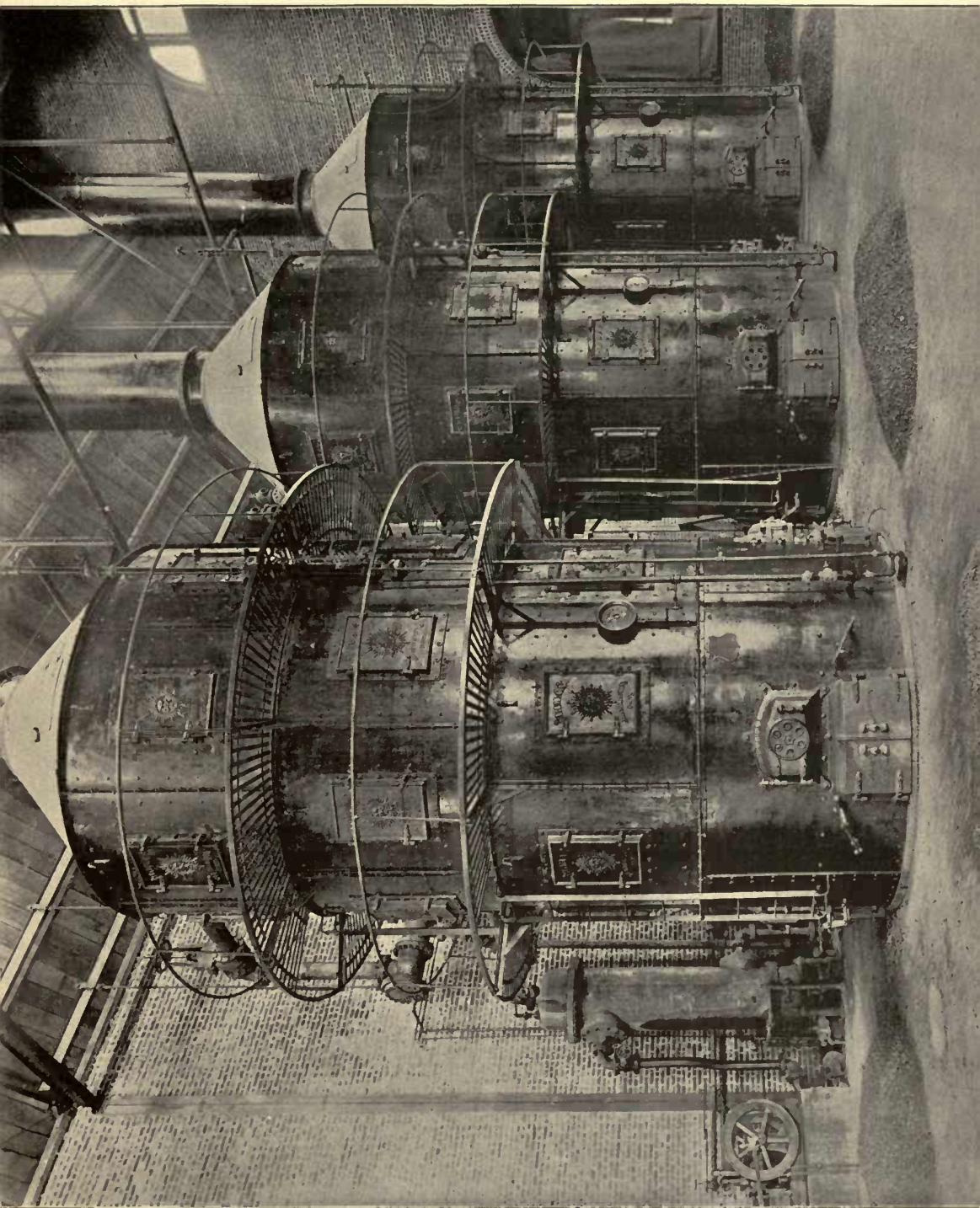
In reference to your test will state for your information that the results were about as follows: The coal used was a very inferior grade of Illinois lump and showed a very large percentage of ash, viz: $24\frac{7}{10}$ per cent. With this coal and with the average temperature of feed water at $167\frac{2}{10}$ degrees, the actual evaporation was $7\frac{43}{100}$ pounds of water to a pound of coal, or $8\frac{8}{100}$ from and at 212 degrees. The evaporation per pound of combustible from and at 212 degrees was $10\frac{77}{100}$ pounds. During the test we burned $25\frac{7}{10}$ pounds of coal per foot of grate surface and developed 515 horse-power on a basis of $34\frac{1}{2}$ pounds of water per horse-power hour.

I am very well pleased with these results and am confident that with the new grate bars and with an average grade of coal, very satisfactory results will be obtained.

Yours truly,

C. H. WILMERDING,

General Manager.



THREE 350 H. P. MORRIN "CLIMAX" BOILERS ERECTED AT THE POWER STATION OF THE JERSEY CITY, HOBOKEN
AND RUTHERFORD ELECTRIC RAILWAY CO., SECAUCUS, N. J.



Brooklyn City and Newtown Railroad Co.

BROOKLYN, N. Y., July 6th, 1893.

CLONBROCK STEAM BOILER WORKS,

564-566 Smith St., Brooklyn, N. Y.

GENTLEMEN :—In reply to your inquiry about the working of our boilers which you erected for us last Fall, I will say that we fired up the first one the 3d of December. Since that time we have increased our work, and since about the middle of February we have had two of the four boilers at work all the time, and sometimes three. We have not yet been at work under the most favorable circumstances, owing to our work of construction not yet being complete, but so far it appears, according to reports made me by our engineer, that we are consuming about three pound of coal (not more) per horse-power per hour.

We are feeding these boilers with water from a driven well upon the premises. After operating about four months, we made a careful examination of the boilers, and found the tubes free from scale. There was scale in the lower part of the shell. We have not used any boiler compound of any kind.

Yours very truly,

JOHN N. PARTRIDGE,
President.

Edison Electric Illuminating Company of Brooklyn.

BROOKLYN, October 18th, 1893.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

DEAR SIRs :—Our Third District Williamsburg Station has been in active operation now for about eight months, and has developed a higher economy than anticipated. We have been able to deliver current in small quantities (small on account of capacity of our conductors) from this station to our First District Station, the delivered current actually costing us 25 per cent. less than current generated in the latter plant.

This low cost of production is due to economy in labor and machinery, and is readily ascribed to the employment of direct connected generators, triple expansion condensing engines, and Climax boilers.

We are very much pleased with the boilers on account of their steaming powers, economy, and low cost of repairs, and we are now putting the same type in our second district.

Trusting you find the Climax meeting with the same welcome in other places, I am,

Yours truly,

W. S. BARSTOW,
Gen'l Supt.

The Essex County Electric Company.

ORANGE, N. J., March 14th, 1893.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Yours of the 6th inst., at hand, and in reply to same would say, we have been using one of your boilers for almost four years, and last Spring we placed a second order, which is about the best recommendation that they are entirely satisfactory.

Yours very truly,

THE ESSEX COUNTY ELECTRIC COMPANY,

WALTER A. HUSTON,

Superintendent.

Riverside Iron Works.

WHEELING, W. VA., March 13th, 1893.

CLONBROCK STEAM BOILER WORKS,

Brooklyn, N. Y.

GENTLEMEN :—Replying to your favor of 6th inst., wherein you state that you are contemplating the issue of a new circular with testimonials, we desire to say that we wish to be recorded as an ardent friend, admirer and user of the Climax Boiler.

Our No. 1, 550 horse-power was put in service June 18th, 1890, and has been in continuous operation, double turn, ever since. No. 2 was started in September, 1890; No. 3 has been in operation since April, 1892, and No. 4 will be fired in about two weeks from this time.

All of our boilers are of the same design and capacity, and have been worked steadily to their full capacity under very trying conditions, with water strongly impregnated with carbonate of lime, and at times carrying large quantities of alluvial soil in suspension. The steam has been supplied to engines doing the heaviest class of rolling-mill work, with constantly varying loads, resulting at first in serious priming, but this was quickly corrected by alterations made by Mr. Morrin, the patentee, who visited our works for that purpose, since which we have at all times had an abundant supply of perfectly dry steam.

The boilers steam quickly and are economical in consumption of fuel.

They are easily fired and cleaned, the fire-box extending entirely around the boiler, which stands on end. The tubes are easily accessible by removing section of the iron casing, and repairs can be quickly made.

They occupy far less floor space for equal capacity than any boiler within our knowledge.

One of the above boilers was furnished with charcoal iron tubes, some of which have been replaced; but the others, equipped with steel tubes, made from Riverside steel, have required very slight repairs, if any.

We are pleased to add that these boilers are doing very satisfactory service, both as regards steaming capacity and the extent of repairs required.

We unreservedly recommend them to users of steam, and our four times repeated orders with you will fully attest our sincerity.

Yours truly,

RIVERSIDE IRON WORKS.

Dictated by

F. J. HEARN, *General Manager.*

Tuxedo Club.

TUXEDO PARK, March 10th, 1893.

CLONBROCK STEAM BOILER WORKS,
Smith Street, Brooklyn, N. Y.

GENTLEMEN:—Your letter of the 6th inst., received. We beg to state that the Climax Boiler gives entire satisfaction.

It is unique in design, perfect in construction, and we believe the best high-pressure and rapid steam generator on the market for power and electric plants. We run our plant night and day.

The Climax has been in this service about two years, making a saving in our coal bills about 37 per cent. over our old boilers, thus the saving for one year is more than enough to pay the entire cost of Climax Boiler and connections.

Yours truly,

EDWARD I. WILBUR,
Chief Engineer Tuxedo Club.

Riverside Iron Works.

WHEELING, W. VA., November 27th, 1893.

CLONBROCK STEAM BOILER WORKS,
Brooklyn, N. Y.

DEAR SIR:—We are just in receipt of your favor of 25th inst., and note your inquiry, and have to say in reply that we have made diligent inquiry at the works to ascertain, if possible, the foundation for report in the newspaper notice referred to, but fail to find the slightest trace of any boiler explosion having taken place in any department of our works, and can therefore only conclude that the story had its origin in the fertile imagination of some newspaper reporter.

We have had to answer a number of letters on the subject, received from different parts of the country, but in reply to these have taken occasion to say that if we were in the market for an additional steam-making plant, we would certainly give the Climax the preference.

We regret that such an unfounded report should have been put in circulation, and hope it will not work any injury to your good selves.

We are, yours truly,

RIVERSIDE IRON WORKS.

Bureau of Paper Clippings, from WHEELING (W. Va.) REGISTER,
October 13th, 1893.

An upright Climax boiler at the Riverside Tube Works bursted a few days ago, but no one was injured. The boiler will be repaired by to-morrow.

THE SAFETY VALVE, November 15th, 1893.

An upright "Climax" boiler exploded at the Riverside Tube Works, W. Va., on the 13th ult. No one was injured.

An Unfounded Report.

AMERICAN MACHINIST, December 28th, 1893.

A report has been circulated to the effect that a "Climax" boiler had exploded at Wheeling, W. Va. Inquiry shows this report to be utterly without foundation, and at the Clonbrock Steam Boiler Works, in Brooklyn, where these boilers are built, there is indignation which may yet find vigorous and unpleasant expression. There has been no mishap to any of the "Climax" boilers at the works where this one is said to be located. A letter which we have seen from an official at the works, not only confirms this, but says that if more boilers were needed they should place the "Climax." We are not surprised at a report of the kind named being started by a daily paper, although published near the scene of the alleged explosion; but it is strange that a technical journal, printed in New York, when a few minutes' investigation would have shown the report to be unfounded, should have published it without confirmation.

SAFETY VALVE, December 15th, 1893.

In our issue of November 15th, there appeared an item under the caption "BOILER EXPLOSIONS," to the effect that "an upright Climax boiler exploded at the Riverside Tube Works, Wheeling, W. Va., on October 13th." The item was taken from a local paper, and the information was naturally presumed to be true. Since then, however, the Riverside Company has denied the truth of the report, stating that no explosion whatever has taken place at its works during the last two years, and that the Climax Boilers are doing good work.

A Correction.

WHEELING REGISTER, March 30th, 1894.

In our issue of October 13th, 1893, an item appeared which read as follows :
"An upright Climax boiler at the Riverside Tube Works bursted a few days ago and no one was injured. The boiler will be repaired to-morrow."

The Clonbrock Steam Boiler Works, the makers of the said Climax boiler, shortly after the article appeared, denied the truth of the article, claiming that their boiler would not explode, and requesting that we make an investigation; we have done so and find that there was no explosion of a Climax boiler at the works of the Riverside Iron Works, or elsewhere, so far as we are able to learn. We make this correction cheerfully in order to prevent any ill effects resulting to the makers of the Climax boilers from the publication of the said item.



TEST OF THE MORRIN CLIMAX STEAM GENERATOR.

Made at P. Lorillard & Co's Tobacco Factory, Jersey City, N. J.

April 26, 1888.

Rated capacity,		325 h. p.
Duration of test,		10 hrs.
Kind of fuel used,	}	soft coal and dust.
Proportions,		1 of soft to 2 of dust.
Average steam pressure,		78 lbs.
Temperature of steam,		330 deg.
Average temperature of feedwater,		168 deg.
Pounds of coal consumed,		9,925 lbs.
“ refuse (ash),		1,360 lbs.
“ combustible,		8,565 lbs.
Percentage of ash,		14 per cent.
Total water evaporated, actual conditions,		106,400 lbs.
“ “ “ from and at 212°,		114,784 lbs.
Horse-power developed, actual conditions,		355 h. p.
“ “ “ from and at 212°,		383 h. p.
Water evaporated per lb. coal, actual conditions,		10.72 lbs.
“ “ “ “ from and at 212°,		11.56 lbs.
“ “ “ “ combustible,		12.42 lbs.
“ “ “ “ “ at 212°		13.40 lbs.
9.10 lbs. fuel for		one cent.
97½ lbs. water evaporated for		one cent.

BOILER TEST—MORRIN CLIMAX BOILER No. 2.

Test made at P. Lorillard & Co's, Jersey City, N. J.

By John Doyle, P. Griffin and P. Driscoll.

September 18, 1890.

Heating surface, ...	3,100 sq. ft.
Grate surface, ...	60 sq. ft.
Ratio of heating to grate surface, ...	51.7 to 1
Kind of fuel used (subject to rainy weather), ...	pea coal.
Duration of test, ...	10 hours.
Average steam pressure, ...	90.5 lbs.
“ temperature of feed, ...	164.5 deg.
Pounds of coal burned, ...	9,400 lbs.
“ refuse, ...	1,519 lbs.
“ combustible, ...	7,781 lbs.
Per cent. of ash, ...	16 per cent.
Coal burned per square foot grate per hour, ...	15.6 lbs.
Total water evaporated, ...	101,430 lbs.
Water evaporated per hour, ...	10,143 lbs.
“ “ “ sq. ft. h. s. per hour, ...	3.27 lbs.
“ “ “ lb. coal, actual conditions, ...	10.79 lbs.
“ “ “ “ “ from and at 212°, ...	11.98 lbs.
Rated horse-power, ...	325 h. p.
Horse-power developed, actual conditions, ...	338 h. p.
“ “ “ from 212°, ...	367.6 h. p.
Water evaporated per lb. combustible, ...	12.88 lbs.
Pounds of fuel for 1 cent, ...	11.2 lbs.
“ water evaporated for 1 cent, ...	120.85 lbs.

BOILER TEST—MORRIN CLIMAX BOILER No. 2.

Test made at P. Lorillard & Co's, Jersey City, N. J.

By John Doyle, P. Griffin and P. Driscoll.

September 20, 1890.

Heating surface, ...	3,100 sq. ft.
Grate surface, ...	60 sq. ft.
Ratio of heating to grate surface, ...	51.7 to 1 ft.
Kind of fuel used, ...	Lehigh egg.
Duration of test, ...	10 hrs.
Average steam pressure, ...	93.6 lbs.
“ temperature of feed, ...	148.5 deg.
Pounds of coal burned, ...	14,700 lbs.
“ refuse burned, ...	1,610 lbs.
“ combustible, ...	13,090 lbs.
Per cent. of ash, ...	10.9 per ct.
Coal burned per square foot grate per hour, ...	24.5 lbs.
Total water evaporated, ...	157,780 lbs.
Water evaporated per hour, ...	15,778 lbs.
“ “ “ sq. ft., h. s per hour, ...	5.09 lbs.
“ “ “ lb. coal, actual conditions, ...	10.73 lbs.
“ “ “ “ from and at 212°, ...	11.89 lbs.
Rated horse-power, ...	325 h. p.
Horse-power developed, actual conditions, ...	525.9 h. p.
“ “ from 212°, ...	580.5 h. p.
Water evaporated per lb combustible, ...	12.05 lbs.
Pounds of fuel for one cent, ...	4.44 lbs.
“ “ water evaporated for one cent, ...	47.64 lbs.

BOILER TEST—MORRIN CLIMAX BOILER No. 2.

Test made at P. Lorillard & Co's, Jersey City, N. J.

By John Doyle, P. Griffin and P. Driscoll.

September 22, 1890.

Heating surface, ...	3,100 sq. ft.
Grate surface, ...	60 sq. ft.
Ratio of heating to grate surface, ...	51.7 to 1.
Kinds of fuel used, ...	dust and soft coal mixture, 3 to 1.
Duration of test, ...	10 hours.
Average steam pressure, ...	94.5 lbs.
“ temperature of feed, ...	162.3 deg.
Pounds of coal burned, ...	12,300 lbs.
“ refuse, ...	1,628 lbs.
“ combustible, ...	10,672 lbs.
Percentage of ash, ...	13.2 per ct.
Coal burned per sq. ft. grate per hour, ...	20.5 lbs.
Total water evaporated, ...	129,605 lbs.
Water evaporated per hour, ...	1,296.05 lbs.
“ “ “ sq. ft. h. s. per hour, ...	4.17 lbs.
“ “ “ lb. coal actual conditions, ...	10.53 lbs.
“ “ “ “ from and at 212°, ...	11.48 lbs.
Rated horse-power, ...	325 h. p.
Horse-power developed, actual conditions, ...	432 h. p.
“ “ “ from 212°, ...	470.8 h. p.
Water evaporated per lb. combustible, ...	12.14 lbs.
Pounds of fuel for 1 cent, ...	10.2 lbs.
“ “ water, evaporated for 1 cent, ...	107.4 lbs.

TEST OF CLIMAX BOILER No. 1.

At the Mount Morris Electric Light Co.

Greenwich and Vandam Streets, New York City.

February 21, 1891.

Rated capacity,	250 h. p.
Kind of fuel consumed,	buckwheat.
Duration of test,	4½ hours.
Average steam pressure,	116.6 lbs.
“ temperature of steam,	350.4 deg.
“ “ feedwater,	64 deg.
Water evaporated, actual conditions,	40,104 lbs.
“ “ from and at 212°,	48,080.69 lbs.
Total horse-power developed,	1,602.69 h. p.
“ “ “ “ per hour,	356.16 h. p.
Percentage over rated capacity,	42.5 per ct.

TEST OF CLIMAX BOILER No. 2.

At the Mount Morris Electric Light Co.

Greenwich and Vandam Streets, New York City.

February 24, 1891.

Rated capacity,	250 h. p.
Kind of fuel consumed,	buckwheat.
Duration of test,	5 hours.
Average steam pressure,	115.33 lbs.
“ temperature of steam,	not taken.
“ “ feedwater,	68.66 deg.
Water evaporated, actual conditions,	42,249 lbs.
“ “ from and at 212°,	50,403.3 lbs.
Total horse-power developed,	1,680 h. p.
“ “ “ “ per hour,	336 h. p.
Percentage over rated capacity,	35.4 per ct.

TEST OF CLIMAX BOILER No. 5.

At the Mount Morris Electric Light Co.

GREENWICH AND VANDAM STREETS, NEW YORK CITY.

February 25, 1891.

Rated capacity,	.	.	.	.	.	.	250 h. p.
Kind of fuel consumed,	.	.	.	.	.	.	buckwheat.
Duration of test,	.	.	.	.	.	.	5 hrs.
Average steam pressure,	.	.	.	.	.	.	114 lbs.
“ temperature of steam,	.	.	.	.	.	.	not taken.
“ “ “ feedwater,	.	.	.	.	.	.	58 deg.
Water evaporated, actual conditions,	.	.	.	.	.	.	43,465 lbs.
“ “ from and at 212°,	.	.	.	.	.	.	52,245 lbs.
Total horse-power developed,	.	.	.	.	.	.	1,741.5 h. p.
“ “ “ per hour,	.	.	.	.	.	.	348.2 h. p.
Percentage over rated capacity,	.	.	.	.	.	.	39.4 per cent.

TEST OF 400 HORSE-POWER MORRIN CLIMAX WATER TUBE BOILER.

Using waste heat from 12 Cylinder Boilers, 30" diameter, 30' long. No. 2 Shaft Boiler House, Susquehanna Coal Co., Nanticoke, Pa., Feb. 30, 1894.

Time.	Meter Readings.	Cu. ft. Meter.	Cu. ft. Corrected.	TEMPERATURE.		PRESSURE.		Pounds Evaporated from and at 212°	Horse-Power.
				Feed Water	Flue.	Spring Gauge.	Mercury Gauge.		
7	126,226.1	122.9	126.59	141°	500°	75	77½	8,607.9	253.2
8	126,349.	113.25	116.65	148°	507°	71½	73½	7,852.6	231.0
9	126,462.25	97.55	100.48	145°	491°	69½	70½	6,789.1	200.0
10	126,559.8	124.2	127.93	127°	480°	68	68½	8,831.5	260.0
11	126,684.0	117.7	121.23	122°	519°	75½	78½	8,247.9	242.6
12	126,801.7	160.8	165.62	144°	517°	79	82½	11,232.9	330.4
1	126,962.5	126.9	130.61	146°	520°	83½	87	8,884.4	260.0
2	127,089.4	233.9	230.62	153°	520° +	82	82	15,464.2	455.0
3	127,313.3	123.75	127.46	137°	520° +	84½	85½	8,736.2	256.7
4	127,437.05								
TOTALS.....		1,210.95	1,247.19					76,506.97	2,488.9
AVERAGE.....		134.55	138.57	139°		76.47	77.78	8,500.77	276.5

Morning coal was poor and dirty. Afternoon coal was clean, No. 7 and No. 8 Mixed.

No. 1 and No. 2 Boilers (North 6) used fan draught only. No. 3 and 4 Boilers (Second 6) used fan and steam blower draught.

COMPARISON OF MORNING AND AFTERNOON EVAPORATION.

Time.	Water Evap. from and at 212°	Per Hour Average.	Horse-Power.
7 to 12 A. M.....5 hours.	40,329 lbs.	8,066 lbs.	237.2
12 to 4 P. M.....4 hours.	44,267.7 lbs.	11,066.9 lbs.	325.5

Horse-power based on evaporation of 34 lbs. water per hour, from and at 212° = 30 lbs., from 100° feed to 70 lbs steam.

TEST OF 400 HORSE-POWER MORRIN CLIMAX WATER TUBE BOILER.

Using waste heat from 12 Cylinder Boilers, 30" diameter, 30' long. No. 2 Shaft Boiler House, Susquehanna Coal Co., Nanticoke, Pa., Feb. 21, 1894.

Time.	Meter Readings.	Cu. ft. Meter.	Cu. ft. Corrected.	TEMPERATURE.		PRESSURE.		Pounds Evaporated.	Pounds Evaporated from and at 212°	Horse-Power.
				Feed Water.	Flue.	Spring Gauge.	Mercury Gauge.			
7	128,429.7	103.3	106.4	165.6°	520°+	76	77	6,475.5	7,010.8	203.2
8	128,531.0	115.2	118.66	154°	520°+	74	73.6	7,250.1	7,930.8	229.9
9	128,646.2	111.5	114.85	157°	520°+	76	77	6,827.32	7,452.7	216.0
10	128,757.7	104.9	108.1	147.6°	520°+	75	76.6	6,617.84	7,237.6	209.8
11	128,862.6	75.5	77.77	121.3°	470°	78	79	4,799.19	5,418.2	157.5
12	128,938.1	87.0	89.6	128°	520°+	81	82	5,520.0	6,198.3	179.7
1	129,025.1	262.1	269.96	150.6°	520°+	85	86.6	16,513.45	18,171.2	526.7
2	129,287.2	233.9	240.9	152°	520°+	83	84.3	14,729.85	16,675.8	483.4
3	129,521.1	158.6	163.4	149°	520°+	68.6	79.6	9,997.63	11,348.4	328.9
4	129,679.7									
TOTALS.....		1,252.0	1,289.61					78,730.88	87,443.8	2,530.1
AVERAGE.....		139.11	143.39	148.8°		78.3	79.3	8,747.87	9,715.9	281.1

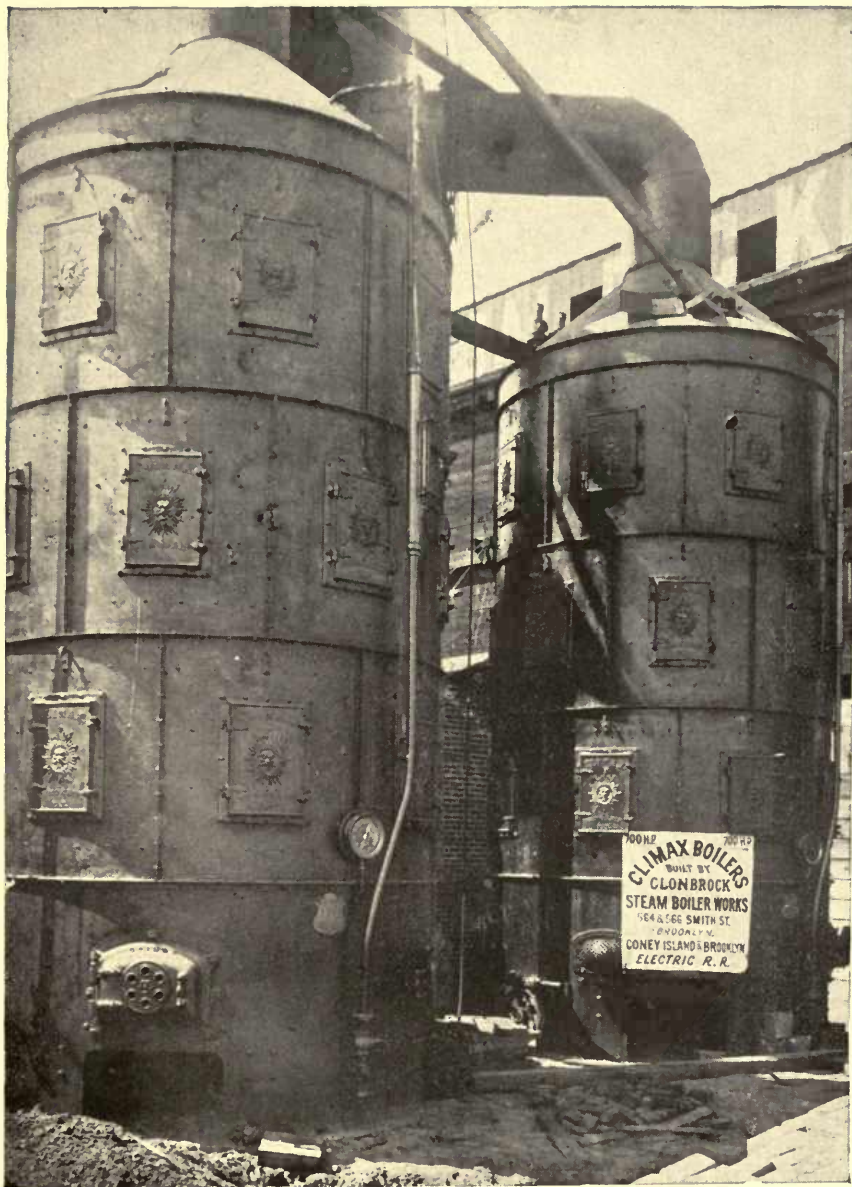
Morning coal was poor and dirty. Afternoon coal was clean, No. 7 and No. 8 mixed. Boilers working under fan blast.

TEST OF 400 HORSE-POWER MORRIN CLIMAX WATER TUBE BOILER.

Using waste heat from 12 Cylinder Boilers, 30" diameter, 30' long. No. 2 Shaft Boiler House, Susquehanna Coal Co., Nanticoke, Pa., March 19, 1894.

Time.	Meter Readings.	Cu. ft. Meter.	Cu. ft. Corrected.	TEMPERATURE.			PRESSURE.		Pounds Evaporated from and at 212°	Horse-Power.
				Feed Water.	Flue before Damper.	Flue after Damper.	Spring Gauge.	Mercury Gauge.		
7	142,821.8	182.5	187.98	148.6	853.	770.	80.6	82.6	12,675.94	367.4
8	143,004.3	254.2	261.83	146.6	742.	666.	78.	80.6	17,681.2	512.5
9	143,258.5	272.7	280.88	126.0	813.	736.	76.3	78.6	19,457.4	564.0
10	143,531.2	287.3	295.92	111.3	873.	850.	75.3	77.3	19,715.5	571.5
11	143,818.5	207.0	213.21	110.6	880.	813.	72.	74.0	15,025.2	435.5
12	144,025.5									
TOTALS.....		1,203.7	1,239.82						84,555.24	2,450.86
Averages for 5 hours run.		240.9	247.98	127.8	831.	767.	76.3	78.7	16,911.05	490.17
Highest av. for 4 hrs. run.		255.3	262.96	124.0	815.5	780.	75.2	77.4	17,947.8	520.86
Highest av. for 3 hrs. run.		271.4	279.54	128.2	805.5	772.	76.1	78.4	18,951.3	549.31
Highest av. for 1 hrs. run.		287.3	295.92	111.3	873.	850.	75.3	77.3	19,715.5	571.46
Run from 12 M. to 1 P. M. cleaning fires.....		190.0	195.70	128.	880.	800.	79.5	81.5	13,535.2	392.32

It commenced to rain about 1 P. M. and continued until 3 to 4 P. M., and the boiler not being roofed or housed in, the evaporation only averaged 363½ horse-power. The coal used was Nos. 7 and 8, or Buckwheat. The water-gauge was kept at nearly the same level during the test, and the water fed regularly. Average outside temperature of air, 60°.



TWO 350 H. P. BOILERS ERECTED FOR THE LONG ISLAND AND BROOKLYN R. R. CO.
BROOKLYN, N. Y.

THIS PLANT CONTAINS NOW, FIVE 350 H. P. MORRIS "CLIMAX" BOILERS.

SUMMARY OF DAILY RUNS.—No. 7 CLIMAX BOILER.

Date.	HP Developed.	COAL.	Amount Dry Coal Burned.	Water Evaporated per lb. Dry Coal.	Coal Burned per HP per Hour.	Per Cent. Ash in Dry Coal.
Nov. 11th.	1079.3	Georges Creek.	36,480	11.73	2.94	8.35
“ 12th.	1191.8	“	38,752	12.2	2.82	9.54
“ 13th.	1134.4	“	40,327	11.16	3.09	8.15
“ 14th.	1167.7	“	41,217	11.24	3.06	8.59
“ 15th.	1101.3	“	34,655	12.06	2.73	7.28
“ 16th.	868.00	{ Screenings and Georges Creek. }	14,773	11.15	3.09	18.55

Average HP for Five Days' Georges Creek Coal, 1134.9

“ “ One Day's Screenings “ “ 868.0

“ lbs. Coal per HP per Hour, . . 2.92

“ “ Mixed “ “ “ 3.09

Summary of Tests, Two 1000 H. P. Climax Boilers, MERRIMAC MILLS, LOWELL, MASS.

SUMMARY OF DAILY RUNS.—No. 8 CLIMAX BOILER.

Date.	HP Developed.	COAL.	Amount Dry Coal Burned.	Water Evaporated per lb. Dry Coal.	Coal Burned per HP per Hour.	Per Cent. Ash in Dry Coal.
Oct. 30th.	942.2	Georges Creek.	31,626	11.80	2.91	8.49
“ 31st.	1011.4	“	33,103	12.12	2.84	9.63
Nov. 1st.	1085.4	“	37,128	11.59	2.97	6.91
“ 2nd.	633.4	{ Screenings and Georges Creek. }	10,804	11.12	3.10	14.5
“ 4th.	1030.9	Georges Creek.	36,864	11.09	3.10	6.46
“ 5th.	954.1	“	30,244	12.51	2.75	9.27
“ 6th.	952.4	“	33,640	11.23	3.07	8.22
“ 7th.	931.7	“	32,130	11.50	2.99	7.64
“ 8th.	890.0	“	30,868	11.44	3.01	7.95
“ 9th.	875.3	“	14,620	11.36	3.03	8.78

Average HP for Nine Days' Georges Creek Coal, 963.7

“ “ One Day's Screenings “ “ 633.4

“ lbs. Coal per HP per Hour, . . 2.96

“ “ Mixed “ “ “ 3.09

The Clonbrock Steam Boiler Company,

Smith, Lorraine, Creamer and Court Streets,

BROOKLYN, N. Y.

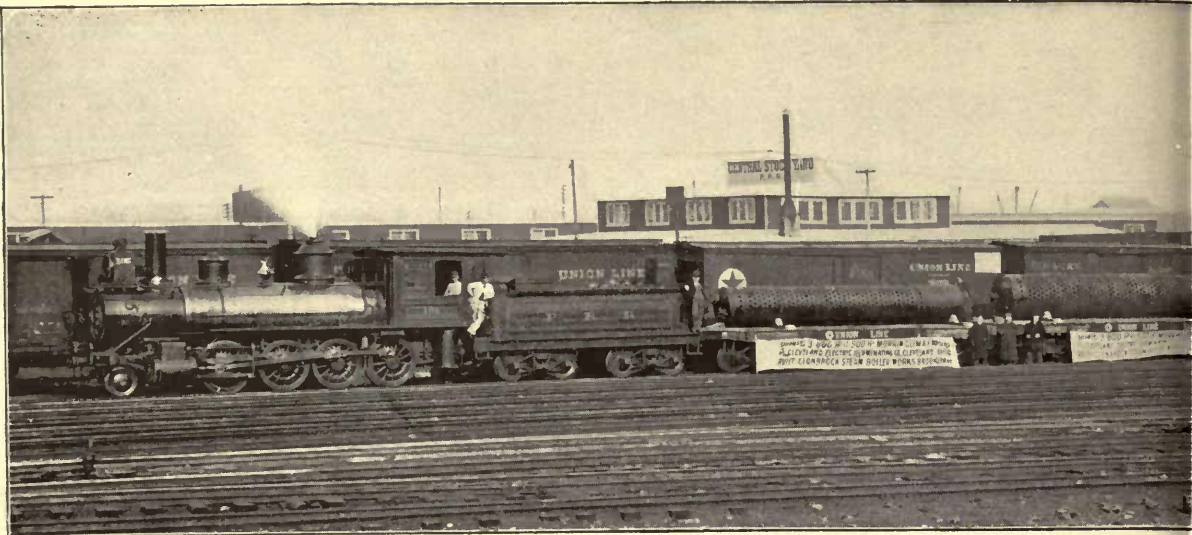
Partial List of Morrin Climax Boilers Installed.

	Number of H. P.	Total H. P.	LOCATION.
One	400	400	American Manufacturing Co., Brooklyn, N. Y.
One	500	500	" " " " "
One	200	200	American Ring Co., Waterbury, Conn.
One	500	500	Atlantic White Lead and Linseed Oil Works, Brooklyn, N. Y.
One	400	400	Atlantic White Lead and Linseed Oil Works, Brooklyn, N. Y.
Two	300	600	Baltimore Traction Co., The, Baltimore, Md.
Two	500	1,000	" " " " " 2d order.
One	600	600	" " " " " 3d order.
One	600	600	" " " " " 4th order.
Two	250	500	Bronx Gas and Electric Co., The, Westchester, N. Y.
Four	350	1,400	Brooklyn City & Newtown R. R. Co., The, Brooklyn, N. Y.
One	350	350	" " " " " " "
			2d order.
One	350	350	Brooklyn City & Newtown R. R. Co., The, Brooklyn, N. Y.
			3d order.
Two	500	1,000	Brush Electric Co., The, Baltimore, Md.
Three	500	1,500	" " " " " 2d order.
Two	500	1,000	" " " " " 3d order.
One	250	250	Buchanan & Lyall Tobacco Works, Brooklyn, N. Y.
One	600	600	" " Planet Mills, Brooklyn, N. Y.
One	800	800	Candee & Co., The L., New Haven, Conn.
Two	350	700	Central Ansonia Sugar Co., Azua, Cuba.
One	500	500	Chicago Arc-Light and Power Co., Chicago, Ill.
One	500	500	" " " " " 2d order.
Two	500	1,000	" " " " " 3d order.
Three	400	1,200	Clearfield Traction Co., Clearfield, Pa.
One	500	500	Cleveland Electric Ill. Co., The, Cleveland, Ohio.
Three	800	2,400	" " " " " "
One	300	300	Coatsworth Elevator, Buffalo, N. Y.
One	300	300	" " " " " 2d order.
One	500	500	Colgate & Co., Jersey City, N. J.

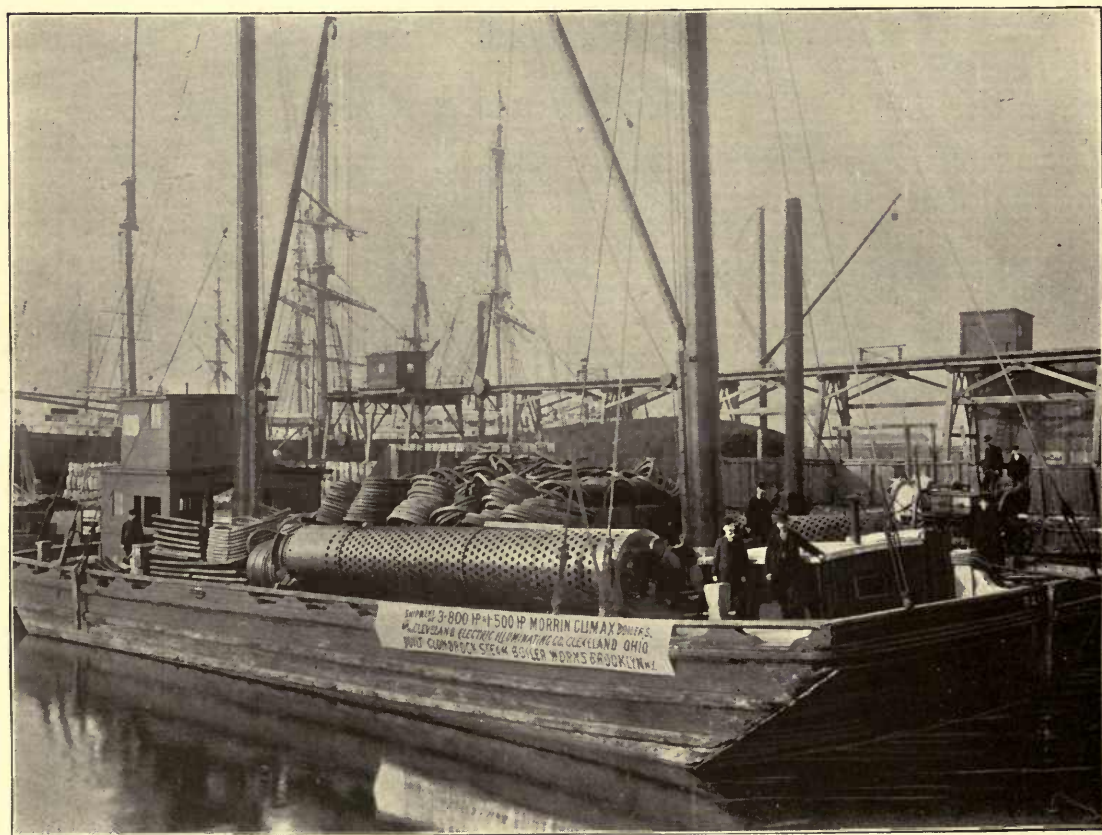


	Number of H. P.	Total H. P.	LOCATION.
Two	600	1,200	Colonial Co., The, Trinidad, W. I.
Two	1,000	2,000	" " " " " 2d order.
Two	500	1,000	" " " San Juan, Porto Rico, 3d order.
Two	350	700	Coney Island & Brooklyn R. R. Co., Brooklyn, N. Y.
One	350	350	" " " " " 2d order.
Two	350	700	" " " " " 3d order.
Four	150	600	Cotting, Chas. E., Trustee, Tremont B'd'g, Boston, Mass.
Two	600	1,200	Craven Supply Co., The, for Edison Electric Light Co., New Orleans, La.
One	250	250	Dieckerkoff, Raffloer & Co., Havana, Cuba.
One	250	250	Eagle Brewing Co., The, Jersey City, N. J.
Three	300	900	Economy Light, Heat and Power Co., Scranton, Pa.
Two	250	500	Edison Electric Ill. Co., The, Brooklyn, N. Y.
One	600	600	" " " " " 2d order.
Two	300	600	" " " " " 3d order.
Two	250	500	" " " " " 4th order.
One	600	600	" " " (Pearl Street Station,) Brooklyn, N. Y., 5th order.
One	600	600	Edison Electric Ill. Co., The, Easton, Pa.
One	600	600	" " " " " 2d order.
One	350	350	Edison Electric Power and Illuminating Co., Lebanon, Pa.
Three	1,000	3,000	Edison General Electric Co., Cincinnati, Ohio.
Three	250	750	" " " " " Newport, R. I.
One	200	200	Essex County Electric Co., The, Orange, N. J.
One	300	300	" " " " " 2d order.
Two	250	500	Ewa Plantation, Kealia Kanai, Hawaiian Islands.
One	250	250	Fowler Hermanos, Cuba.
One	500	500	Gloucester Mfg. Co., The, Gloucester City, N. J.
One	600	600	" " " " " 2d order.
One	200	200	Haverhill Gas Light Co., Haverhill, Mass.
One	200	200	Hazelton Steam Heating Co., Hazelton, Pa.
One	250	250	Hind & Harrison Plush Co., The, Clark's Mills, Oneida Co., N. Y.
Two	600	1,200	Jersey City Elec. Light and Power Co., Jersey City, N. J.
One	600	600	" " " " " 2d order.
Three	350	1,050	Jersey City, Hoboken and Rutherford Electric R. R. Co., Secaucus, N. J.
One	350	350	Jersey City, Hoboken and Rutherford Electric R. R. Co., Secaucus, N. J., 2d order.
One	350	350	Jewell Milling Co., Brooklyn, N. Y.
One	500	500	" " " " " 2d order.
One	250	250	Latimir & Fernandez, St. Johns, Porto Rico.
One	300	300	Leisenring & Co., Minersville, Pa.
One	275	275	Lorillard Co., P., Jersey City, N. J.
One	350	350	" " " " " 2d order.
One	500	500	" " " " " 3d order.
One	150	150	Lorillard Yacht "Reva."
One	50	50	" " " "Lillian," 2d order.
One	90	90	" " " "Caimen," 3d order.





SHIPMENT OF THREE 800 H. P. AND ONE 500 H. P. MORRIN "CLIMAX" BOILERS FOR T

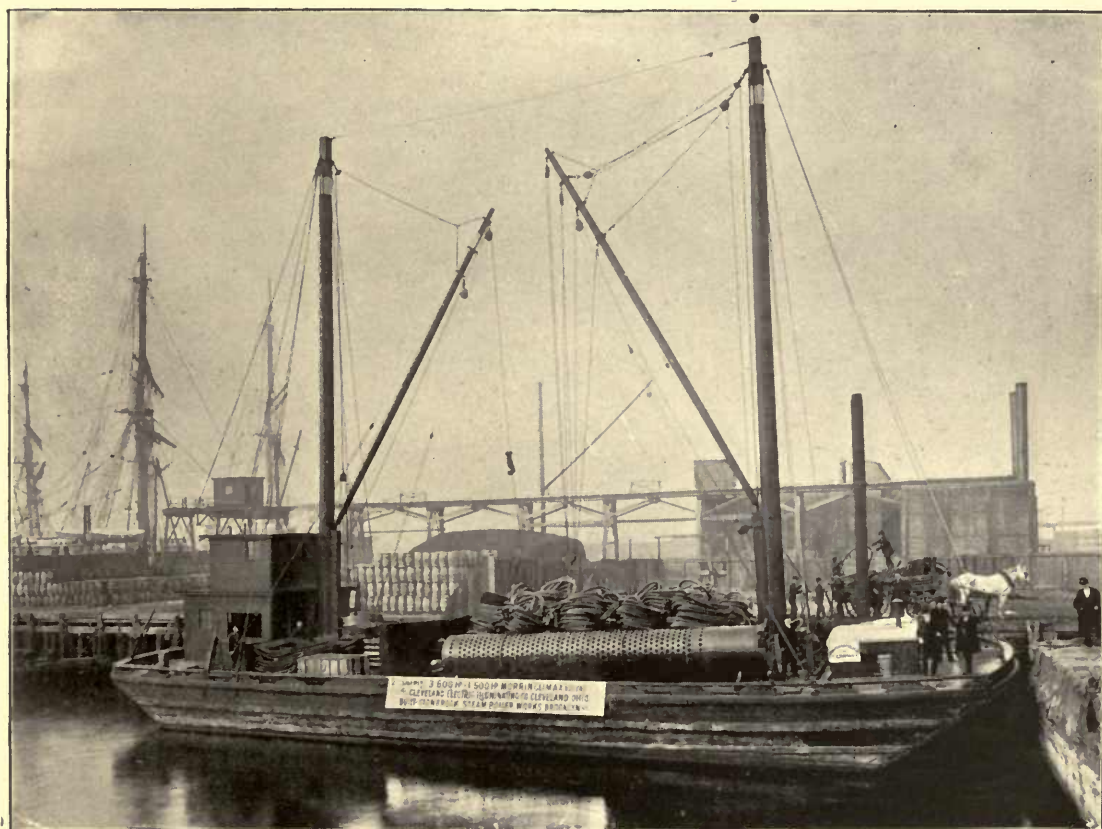


FIRST SHIPMENT OF THREE 800 H. P. AND ONE 500 H. P. MORRIN "CLIMAX" BOILERS,
FOR THE CLEVELAND ELECTRIC ILLUMINATING CO., CLEVELAND, OHIO.

VIEWS SHOWING BOILERS LOADED ON LIGHTERS FROM OUR



CLEVELAND ELECTRIC ILLUMINATING CO., CLEVELAND, OHIO, NOVEMBER, 1894.



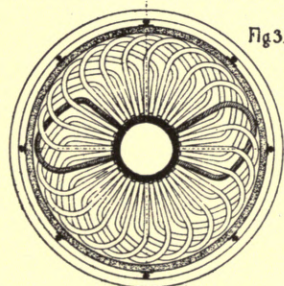
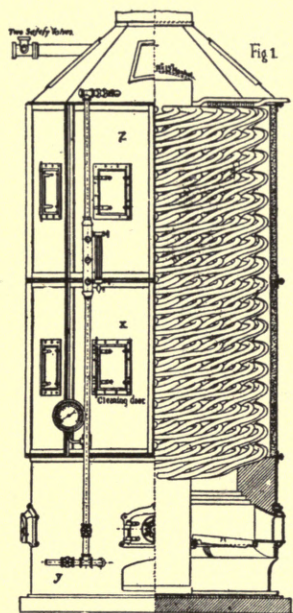
SECOND SHIPMENT OF THE THREE 800 H. P. AND ONE 500 H. P. MORRIS "CLIMAX" BOILERS,
FOR THE CLEVELAND ELECTRIC ILLUMINATING CO., CLEVELAND, OHIO, 1894.

KS AND READY FOR TRANSFERRING TO RAILROAD STATION.

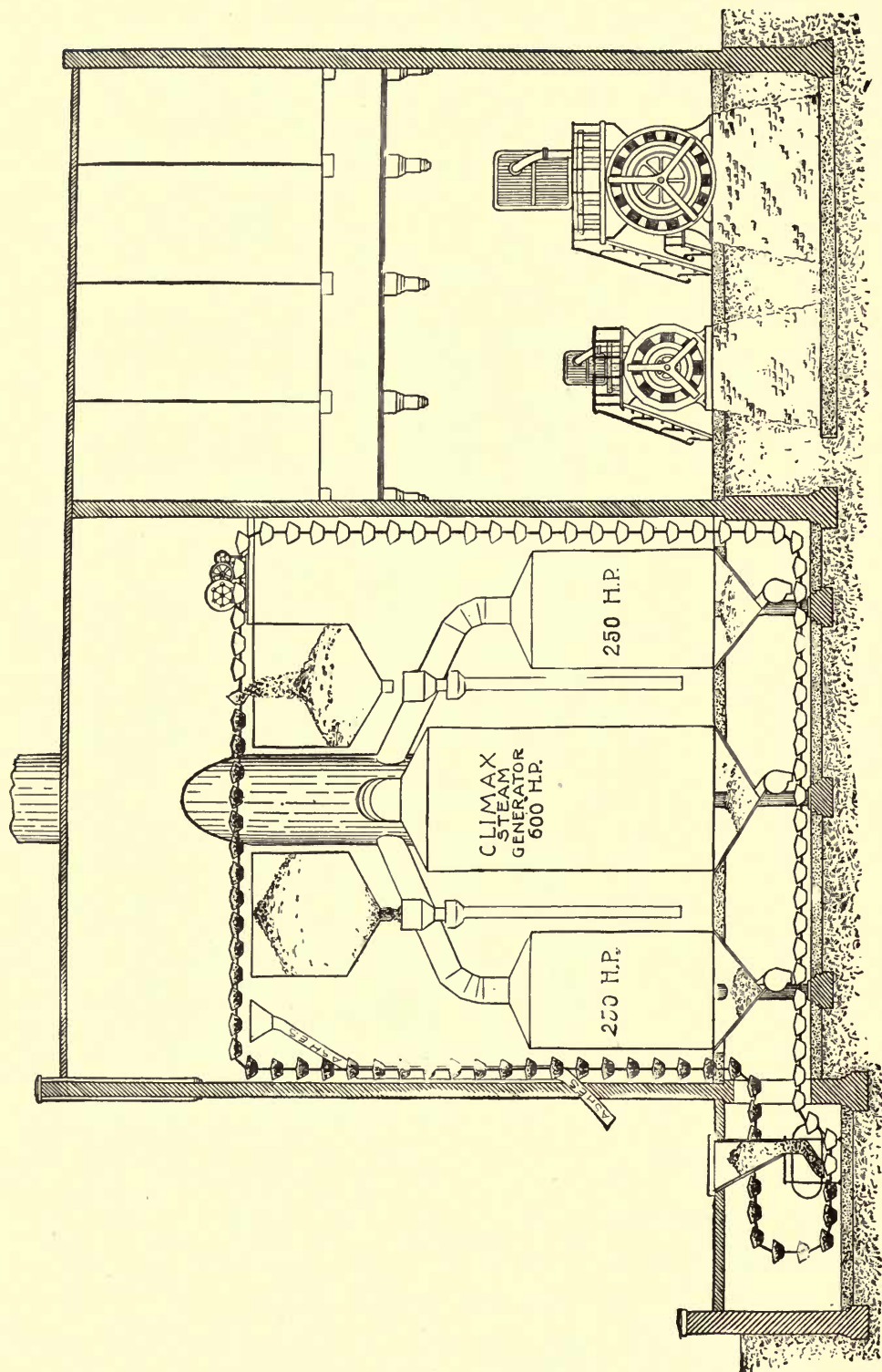


	Number of H. P.	Total H. P.	LOCATION.
One	300	300	Lutgardita Estado, Cuba, 2d order.
One	350	350	Madison Square Electric Light Co., East 24th St., New York City, 3d order.
One	350	350	Makee Sugar Co., Kealia Kauai, Hawaiian Islands.
One	300	300	Manufacturers' Electric Co., Philadelphia, Pa.
One	300	300	" " " " 2d order.
One	500	500	Markle & Co., G. B., Jeddo, Pa.
One	150	150	Marshall Paper Co., Turner's Falls, Mass.
One	200	200	McNab & Harlin Mfg. Co., Paterson, N. J.
Two	350	700	Mellor, Santiago W., Santiago, Cuba.
Two	1,000	2,000	Merrimack Manufacturing Co., Lowell, Mass.
One	300	300	Mt. Jessup Coal Co., Winton, Pa.
Five	250	1,250	Mt. Morris Electric Light Co., The, New York City, 1st, 2d and 3d orders.
One	600	600	Mt. Morris Electric Light Co., The, New York City, 4th order.
Four	450	1,800	Municipal Electric Light Co., Brooklyn, N. Y.
One	250	250	National Starch Company, The, Glen Cove, L. I.
Three	500	1,500	Newark Electric Light & Power Co., The, Newark, N. J.
Two	500	1,000	" " " " " " 2d order.
Two	500	1,000	" " " " " " 3d order.
Two	600	1,200	Newark Electric Light & Power Co., The, Newark, N. J. 4th order.
Two	500	1,000	New Britain Electric Light Co., New Britain, Conn.
One	500	500	" " " " " " 2d order.
One	250	250	New Jersey & Penna. Concentrating Works, Edison, N. J.
One	250	250	Newport Illuminating Co., Newport, R. I., 2d order.
One	600	600	New York Belting & Packing Co., Passaic, N. J.
One	50	50	New York Biscuit Co., The, Newark, N. J.
Two	500	1,000	" " " " New York City, 2d order.
One	1,000	1,000	New York Steam Heating Co., Station B., New York City.
One	1,000	1,000	" " " " Station A., " "
Two	1,000	2,000	2d order.
Two	1,000	2,000	New York Steam Heating Co., New Station, 59th Street and East River, New York City, 3d order.
One	500	500	New York Tartar Co., Brooklyn, N. Y.
Two	300	600	Nichols, W. P., Experanza Plantation.
One	500	500	Pardee & Co., A., Hazelton, Pa.
One	300	300	Pennsylvania Railroad Co., Mt. Holly, N. J.
Two	600	1,200	People's Light & Power Co., Orange, N. J.
One	200	200	Piedmont Electric Ill. Co., Lynchburg, Va.
One	200	200	Providence Gas Co., Providence, R. I.
Two	550	1,100	Riverside Iron Works, Wheeling, W. Va.
One	550	550	" " " " 2d order.
One	550	550	" " " " 3d order.
One	550	550	" " " " 4th order.
One	550	550	" " " " 5th order.
Two	550	1,100	" " " " 6th order.
One	550	550	" " Steubenville, Ohio, 7th order.

	Number of H. P.	Total H. P.	LOCATION.
Two	600	1,200	Safety Electric Light Co., West 24th St., New York City.
One	400	400	San Francisco Bridge Co., New Dredge.
One	250	250	Schenectady Street Railway Co., Schenectady, N. Y.
One	250	250	" " " " 2d order.
One	400	400	Summit Branch Railroad Co., The, Williamstown, Pa.
One	400	400	" " " " 2d order.
One	400	400	Susquehanna Coal Co., The, Nanticoke, Pa.
One	400	400	" " " " 2d order.
One	400	400	" " " " 3d order.
Two	400	800	" " " " 4th order.
One	500	500	Terre Haute Electric Railway Co., Terre Haute, Ind.
One	500	500	" " " " 2d order.
One	350	350	Thomson-Houston Electric Co., East 24th Street, New York City.
One	500	500	Thomson-Houston Electric Co., East 24th Street, New York City, 2d order.
One	50	50	Tuxedo Park Association, Tuxedo, N. Y.
One	100	100	" " " " 2d order.
Two	500	1,000	United Electric Light and Power Co., The, East 29th St., New York City.
One	600	600	United Electric Light and Power Co., The, East 29th St., New York City, 2d order.
Twelve	600	7,200	United Electric Light and Power Co., The, Foot East 29th St., New York City, 3d order.
One	400	400	Upper Lehigh Coal Co., The, Upper Lehigh, Pa.
One	200	200	Van Wickle, A. S., Beaver Meadow, Pa.
One	250	250	" " " " 2d order.
One	250	250	Water Department, North Attleboro, Mass.
One	250	250	Watkinson, Geo., Philadelphia, Pa.
One	300	300	" " " " 2d order.
Two	500	1,000	Westinghouse Electric and Mfg. Co., Pittsburgh, Pa.
Two	350	700	Wilmington City Electric Co., The, Wilmington, Del.
One	300	300	Wolseley, W. A., Trinidad, W. I.
Two	500	1,000	World's Columbian Exposition, Jackson Park, Chicago, Ill.
One	1,000	1,000	" " " " "
One	500	500	Wurster & Co., Kent Avenue, Brooklyn, N. Y.
Three	300	900	Yngenio Lutgardita, Cuba.
One	250	250	Yngenio Santa Ana, Cuba.
Two	500	1,000	Yngenio Tinguaro, Cuba.
One	500	500	Yngenio Victoria, Cuba.



100 H. P. MORRIN "CLIMAX" BOILER.



GWINNETT STREET STATION OF THE EDISON ELECTRIC ILLUMINATING CO., BROOKLYN, N. Y.
SHOWING TWO 250 H. P. AND ONE 600 H. P. MORRIS "CLIMAX" BOILERS.

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DIMENSIONS OF STANDARD SIZE CLIMAX BOILERS.

Horse-Power.	Number of Tubes.	Diameter of Tubes.	Diameter of Central Shell.	Height of Central Shell.	Diameter of Outside Casing or Floor Space.	Diameter of Upper Casing.	Height of Outside Casing to Top of Canopy.	Grate Surface, Sq. Ft.	Heating Surface.	Steam Opening.	Safety Valves.	Safety Valves.	Size of Blow-off Opening.	Diameter of Flue Opening.	Weight Without Water.	Weight Ready for Service.	Horse-Power.
50	280	1 1/4"	24"	10' 1"	6' 6"	6' 9"	11' 5"	20.4	500	2 1/2"	1	2 1/2"	1"	20"	11,000	13,300	50
75	324	1 1/2"	30"	11' 2"	7' 1"	7' 4"	12' 7"	23.7	750	3 3/8"	1	2 3/8"	1"	22"	13,400	15,840	75
100	432	1 3/4"	36"	12' 9"	8' 0"	8' 3"	14' 2"	33.14	1,000	4"	2	2 3/4"	1 1/4"	24"	31,600	38,100	100
125	360	2"	38"	15' 5"	9' 0"	9' 3"	17' 6"	41.9	1,250	4"	2	2 3/4"	1 1/4"	26"	34,300	40,000	125
150	310	2 1/4"	40"	16' 2"	10' 0"	10' 3"	18' 0"	47.4	1,500	5"	2	2 3/4"	1 1/4"	28"	38,000	46,000	150
200	330	2 1/2"	42"	17' 7"	10' 3"	10' 8"	19' 10"	49.84	1,990	5"	2	3"	1 1/2"	30"	42,000	51,700	200
250	390	2 3/4"	42"	19' 5"	10' 11"	11' 6"	21' 6"	59.4	2,500	6"	2	3"	1 1/2"	36"	45,000	56,535	250
300	420	2 3/4"	42"	20' 9"	11' 6"	11' 9"	23' 1"	68.3	3,000	6"	2	3"	2"	38"	55,800	69,640	300
350	375	3"	42"	24' 9"	11' 2"	11' 2"	27' 2"	73.2	3,500	6"	2	3 1/2"	2"	42"	65,700	83,385	350
400	400	3"	42"	25' 6"	12' 0"	11' 2"	27' 6"	76.3	3,950	8"	2	3 1/2"	2"	44"	71,400	88,320	400
500	475	3"	42"	29' 2"	12' 8"	12' 8"	31' 4"	88.23	4,960	8"	2	3 1/2"	2 1/4"	48"	83,300	106,400	500
600	588	3"	48"	31' 0"	13' 0"	13' 0"	33' 6"	109.32	5,980	8"	2	4"	2 1/2"	52"	92,300	120,300	600
800	720	3"	52"	34' 4"	15' 0"	13' 9"	36' 10"	127.52	7,890	10"	2	4"	2 1/2"	56"	112,100	150,650	800
1,000	928	3"	56"	39' 10"	17' 0"	14' 3"	42' 8"	175.0	9,525	12"	2	5"	3"	60"	131,900	181,000	1,000

Prices cover Boiler erected complete on foundations furnished by purchaser.

THE CLONBROOK STEAM BOILER COMPANY,

Smith, Lorraine, Creamer and Court Streets,

BROOKLYN, N. Y.

RULES

FOR MANAGEMENT AND CARE OF

THE MORRIN "CLIMAX" BOILER.

Low Water.

In case of low water, immediately bank or cover the fires with ashes or if no ashes are at hand, use fresh coal and check draft. Don't turn on the feed under any circumstances, nor tamper with or open the safety valve. Let the steam outlets remain as they are, even if engines are running.

In Cases of Foaming.

Close the throttle and keep closed long enough to show true level of water. If that level is sufficiently high, feeding and blowing out will usually suffice to correct the evil. In cases of violent foaming caused by dirty water, or change from salt to fresh or *vice versa*, in addition to the action before stated, check draft and cover fires with fresh coal. A little kerosene added to feed water will usually settle the water at once.

Safety Valves.

Raise the safety valves cautiously at least once in twenty-four hours, as they are liable to become fast in their seats, and useless for the purpose intended.

Safety Valve and Pressure Gauge.

Should the gauge at any time indicate the limit of pressure allowed, see that the safety valves are blowing off. In case of difference, find out which is wrong and rectify it.

Gauge Cocks. Glass Gauge.

Keep gauge cocks clear and in constant use. Do not open them too suddenly. Glass gauges should not be relied on altogether.

Leaks.

When leaks are discovered they should be repaired as soon as possible.

Clean Sheets.

Particular care should be taken to keep sheets and parts of boilers exposed to the fire perfectly clean. Keep all tubes clean, particularly when wood or soft coal is used for fuel.

Blowing Off.

Blow off at least once in two weeks,—every Saturday night would be better. In case the feed water is muddy, blow down a few inches every day. Boilers should never be blown out while hot, as the furnace walls retain sufficient heat to bake the deposits of mud into a hard scale that becomes firmly attached. Furnace should always be allowed to cool down before the water is run out; the deposit of mud will then be quite soft and can be easily washed out with a hose. Many engineers suppose that blowing out a boiler under pressure has a tendency to remove these deposits from a boiler, but experience has shown this to be a very grave mistake.

Filling up the Boiler.

Cold water pumped into hot boilers is very injurious, causing severe contraction of the seams which very often causes fracture or leakage in the seams and tubes. Many boilers, well constructed and of good material, have been ruined by being blown out under a high pressure of steam and then suddenly filled with cold water. This treatment is so highly productive of strained and leaky tubes, since being of thinner material than the shell, they cool and contract sooner.

Removing Deposit and Sediment.

In the "Climax" the bottom plate should be removed once in four weeks, for the removal of heavy sediment.

Prevention of Scale.

There are many compounds used for prevention of scale, some are good and others are not so good. Each engineer will have to judge for himself as to methods of meeting conditions to suit each particular case. Kerosene intelligently used however, seems to give uniformly good results.

General Care of Boilers and Connections.

In firing with coal keep your grates well covered with a thin fire. Do not feed your fire with large lumps or throw in too much fresh coal at one time. A thin fire lightly and frequently renewed is the most economical. No coal should be allowed to accumulate on dead plates in front of fire doors.

If your boiler steams too fast close your dampers and shut off the draft. Never open your fire doors when it can be avoided. To keep them open longer than is absolutely necessary, is injurious to the boiler and wasteful of fuel.

Keep gauges, cocks, etc., clean and in good order at all times and gauge your pump so that the feed may be constant.

USEFUL INFORMATION.

STEAM BOILERS.

This is not a new subject, but it is most certainly a topic that ought to be of interest to the whole community, as well as of vital importance to manufacturers and engineers. "What is a steam boiler and what is its use?" Generally speaking, it is a closed metallic vessel, both strong and tight, in which steam is generated from water by the application of heat, for the purpose of giving motion to machinery or supplying heat in a more convenient manner to places where it is needed.

But a boiler is not complete without certain fixtures, appendages and accessories. There must be a feed pump or injector, with a supply pipe, feed pipe, feed valve, safety feed valve and check valve, in order to supply water properly to the boiler; gauge cocks and glass water gauge, to show the height of the water in the boiler, or water level as it is more commonly called; a heater, to assimilate the temperature of the feed water as nearly as possible to that of the water in the boiler; a blow pipe with its valve, to reduce the height of the water in the boiler or to empty it entirely; a safety valve, to allow the steam to escape from the boiler when it exceeds a fixed pressure, in order to prevent strains or rupture; a steam pipe, to convey the steam to the place where it is wanted; a reverse or atmospheric valve, to prevent the formation of a vacuum in the boiler, and thus avoid collapsing strains; manhole and handholes, with plates and guards, for examination and cleaning; a steam gauge, to indicate at all times the pressure in the boiler, and a fusible plug to give warning in case of "low water," although this last is not absolutely a necessity; all flat surfaces should be well braced. All these are attachments to the boiler proper, having direct reference to its internal functions; but in addition there are lugs or brackets which support the boiler; the masonry in which it is set, with its binders, rods and wall plates; the boiler front, with doors, anchors, bolts, etc.; the arch plates, bearer bars, grate-bars and dampers; and last, but not least, the chimney or stack and its topping. These are all equally necessary to enable the boiler to perform its duty properly; and besides there are required fire tools, tube brushes and scrapers, coal shovel and scaling tools, and hose to wash-out with, and hammer, chisels and wrenches. Thus we see that in speaking of the boiler, not only the boiler proper is meant, but also the whole of its fixtures appendages and belongings, making quite an assemblage of different parts and pieces, each and all of which must be kept in good condition at all times, in order to insure safety and obtain the best results possible as regards the generation of steam.

It is proved by experience that a furnace may consume a large quantity of fuel without perfect combustion taking place, and when it does take place, a comparatively small portion of it may be usefully employed. One pound of coal can be made to evaporate 14 to 15 lbs. of water, but in practice 10 lbs. is seldom exceeded, showing that even when at its best, the efficiency of the boiler is comparatively small, but if there is either an excess or an insufficient supply of air admitted, or there is a bad draught or bad stoking, the efficiency is still further reduced. When combustion has been completed in the combustion chamber, the evaporative power of that portion of the boiler is high, and it is the most efficient for transmitting heat to the water.

The internal efficiency of the boiler depends, to a great extent, on the circulation of the water to and from the heating surfaces, it being a well-known fact that a boiler with a bad circulation is not nearly so efficient as one having a good circulation.

FUEL.

There is often required for use of boilers nearly twice as much fuel as would be necessary if the plant were of different type and more skilfully managed; the reason for this is that:

- (1) The engines use too much steam to develop the power required by being either under or over-loaded, generally the latter.
- (2) Boilers are badly designed, improperly set or too small.
- (3) Coal is poor quality or improperly housed (coal loses from *ten to forty* per cent. of its evaporative effect being exposed to the weather).
- (4) The firemen are ignorant or careless.

Two and one-half pounds of good dry wood is equivalent in evaporative effect to one pound of coal.

The usual waste of Anthracite coal is about 16½ per cent., while that from Cumberland coal is only about one-half so much.

In buying Anthracite coal, that quality should be selected which has a bright appearance and a conchoidal fracture. If of dull appearance and shows seams or cracks it will fly into fragments in the furnace and not prove economical.

With bituminous coal, if the fractures show a whitish film or rusty stains, they are indications of sulphur and iron Pyrites and should be rejected for furnace use.

Fuel is often wasted from the grate bars not being properly spaced.

Wood as Fuel.

It is generally conceded that 2½ lbs. of good dry wood are equivalent in evaporative effect, to 1 lb. of good coal, but it must be remembered that wood requires a roomier furnace than coal and also that the spaces between the grate bars must be larger.

The fuel value of the same weight of different woods is very nearly the same; that is, a pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. If the value be measured by weight it is important that the wood be dry, as each ten per centum of moisture in the wood will detract about 12 per centum from its value as a fuel.

The weights of one cord of different woods (air dried) as well as the fuel value in comparison with coal, is as follows:

One cord of hickory or hard maple weighs 4500 lbs. and is equivalent to 2000 lbs. of coal.

One cord of white oak weighs 3850 lbs. and is equivalent to 1715 lbs. of coal.

One cord of beech, red oak or black oak weighs 3250 lbs. and is equivalent to 1450 lbs. of coal.

One cord of poplar (white wood), chestnut or elm weighs 2350 lbs. and is equivalent to 1050 lbs. of coal.

One cord of the average pine weighs 2000 lbs. and is equivalent to 925 lbs. of coal.

Air space in grate-bars to burn wood is from three-quarters to one inch.

One cord of wood equals 128 cubic feet.

One ton of Anthracite coal about 42 cubic feet.

Foreign Matter in Water.

It may be as well to show how an engineer can ascertain for himself what foreign matters are present in the water he feeds into his boilers. Below is a list of what is required:

One-half pint bottle of Soap Solution.

One 2 oz. bottle of Lime Water.

One 2 " " Chloride of Barium.

One 2 " " Ferrocyanide of Potassium.

One 2 " " Hydrochloric Acid.

One 2 " " Nitric Acid.

One 2 " " Tincture of Cochineal.

One 2 " " Metallic Mercury.

One 2 " " Carbonate of Ammonia
(crystals).

One 1 oz. bottle of Oxalic Acid (crystals).

One 1 " " Phosphate of soda
(crystals).

Slips of Blue and Red Litmus Paper.

One 4 oz. Flat Bottom Clear Glass Bottle.

One Wooden Test Tube Holder.

One small Spirit Lamp.

One-half pint of Alcohol.

One Test Tube Brush.

One-half dozen of Test Tubes.

These can be supplied by any chemist. Then take a clean bottle and fill it with the water you desire to test and proceed as follows:

To see whether the water is hard or soft: Take a clean test tube and pour into it about three-quarters of an inch in depth of the soap solution, then pour into it three or four drops only of the water; if it becomes milky or curdy the water is hard.

To see if the water is alkaline or acid: Dip into a test tube half filled with the water a strip of red litmus paper; if it does not turn blue, the water is not alkaline; now dip a strip of the blue litmus into the water, if it does not turn red the water is not acid.

To see if there is carbonic acid: Fill about three-quarters of an inch of water into a test tube, and then pour in just as much lime water; if there is carbonic acid, the water will become milky, and on adding a little hydrochloric acid the water will become clear again.

TEST FOR SULPHATE OF LIME (GYPSUM).—Fill in the water to the depth of one and one-half inches in a test tube and then add a little chloride of barium; if a white precipitate is formed and it will not re dissolve when you add a little nitric acid, sulphate of lime is present.

TEST FOR MAGNESIA.—Fill a test tube one-fourth or one-third full with the water; hold it with tube holder and bring it to a boil over the spirit lamp; then add the point of a knife full of carbonate of ammonia, and a very little phosphate of soda; if magnesia is present it will form a white precipitate; but as it may not do so at once it is best to set it one side for a few moments.

TEST FOR LEAD.—Fill a test tube one-fourth full of water, and add one or two drops only of tincture of cochineal. If there be only a trace of lead in the water it will be colored blue instead of pink.

TEST FOR COPPER.—Add to some water in a test tube, a little filing dust of soft iron and a few drops of chloride of ammonia, a blue colorization denotes the presence of copper.

TEST FOR IRON.—To some water, in a test tube, add one drop of ferrocyanide of potassium; it will color it blue if iron be present.

What is Steam?

We might say steam is a vapor formed from water by heat, but that is not sufficient.

The passage of any liquid into the gaseous state is called vaporization; the term evaporation especially refers to the slow production of vapor at the free surface of a liquid, and boiling to its rapid production in the mass of the liquid itself the term vapor is confined to evaporation without boiling or ebullition, which is commonly understood to take place at a temperature of 212° Fahr. or above it.

The experiments of Arago, Dulong, Regnault and others have long since determined that the boiling point of fresh water at the sea level, under the pressure of the atmosphere corresponding to a height of 22.92 inches of the mercurial barometer is 212° Fahr. or 100° centigrade, and also that if the water is confined in a vessel under pressure, the temperature of the boiling point of the water rises when the pressure is increased, though not in the same ratio; but the same amount of pressure always corresponds to the same temperature of the boiling point in the same liquid.

And again, if the water is not pure or nearly so, but holds various salts in solution, the temperature of the boiling point is thereby increased for the same pressure. For instance, the boiling point of sea water which contains salts of lime, magnesia and sodium is 213.4° Fahr. under the pressure of the atmosphere.

It will be well also to recollect that on the top of a high mountain the pressure of the atmosphere is less than at the sea level, and of course there will be less pressure on the surface of a body of water there, and consequently it will boil at a lower temperature and its steam will have less tension.

A liquid boils when the tension of its vapor is equal to the pressure it supports.

The particles of water are strongly cohesive; but the particles of steam are repellant. It takes a certain amount of fuel to raise the temperature of a cubic foot of water from 60° Fahr. to the boiling point—212° Fahr.; but to further raise the water into steam the same identical temperature would require a still further expenditure of fuel.

Now what becomes of the extra amount of heat developed by this additional amount of fuel? It is not shown by the thermometer; it is absorbed in driving apart the particles of water and keeping them apart in the gaseous state as steam, and it is called "latent heat" while thus employed; but when the steam is condensed it manifests itself by increasing the temperature of the water used for its condensation.

The amount of heat thus absorbed varies with the temperature, and has been very thoroughly investigated by Regnault who has tabulated his results, completely overthrowing the old idea that the sum of the sensible and latent heats was always a constant at all pressures.

In order to generate steam in a boiler it is necessary to fill it with water to the proper height, then to start a fire in the furnace to produce ebullition of the water, and to have the safety valve weighted to the tension required of the steam; that all seems easy enough to do, and it really is when you know how to do it.

Boilers may be divided into three divisions or classes—those having internal furnaces, those which are externally fired, and those having detached furnaces or ovens. And again these classes comprise two divisions—those in which the heated gases pass from the furnace through flues or tubes surrounded with water on their way to the chimney, and those in which the gases pass between and among tubes filled with water. The latter are called "Water Tube" boilers; there are also various patented boilers composed almost entirely of tubes filled with water which are generally known by the names of the patentees, but they are all classed as tubulous boilers.

The kinds more generally used in this country are "shell" boilers as the "fire" and "water tube" boilers are often called to distinguish them from the "tubulous" or "pipe" boilers, and they are: the Plain Cylinder, Flue, Drop Flue, Return Tubular, Double Cylinder, Union, Sullivan, Locomotive or Fire Box, Cornish, Lancashire, Galloway, Upright Tubular, Hog Nosed, etc. Besides these there are many patented "shell" boilers, some of them possessing considerable merit.

Weight of Water.

1	Cubic in.		.03617
12	"		.434
1	Cubic ft. (salt)		64.3
1	"		62.5
1	Cylindrical in.		.02842
12	"		.341
1	" ft.		49.10
1	Imperial gal.		10.
1	U. S.		8.355
268.8	"		2240.
1	Cubic foot of water equals	7.48052 U. S. gallons.	
1	Cylindrical foot	" 6.0 " "	

Webster's Definition of Tensile Strength Capable of Extension Boilers.

All material things are subject to tension and compression, and those of fibrous constitution we may conceive to be held together by the attraction of cohesion. We use these terms the better to illustrate our subject—Tensile Strength of Boilers.

Suppose we suspend a rope or wire that will carry say 100 lbs.—no more, no less; now any number of such ropes or wires sustaining 100 lbs each. The absolute cohesive strength of all together would be expressed by the number of weights equaling their combined strength. In a similar manner let us experiment with square bars of iron each having a square inch of section, or one inch each way. Suppose nine of these be separately suspended, or suppose they be united together in one row forming a bar nine inches wide by one inch thick, or suppose they be united in a square measuring three inches each way, there can be no difference in their combined strength or weight. Then knowing the weight each particular rope, wire, or rod sustains, having a sectional area of one square inch, we can estimate the weight of any other dimensions of similar material by calculating the number of square inches, or fractions thereof, in its sectional area. Then suppose we find by experiment the average strength of a bar of wrought iron one square inch in section to be 30 gross tons equal to 67,200 lbs., what will be the strength of a bar ten inches wide and ten inches thick? The sectional area will be $10 \times 10 = 100$ square inches $\times$ by 30 tons = 3,000 tons, and 67,200 lbs. $\times$ by 100 square inches = 6,720,000 lbs. And the strength of a round bar one inch diameter, and area. $.7854 \times 30$ tons = $23\frac{1}{2}$ tons plus; and $67,200 \text{ lbs} \times 0.7854 = 52,780 \text{ lbs}$. This mode of calculation proceeds on the simple principle that every row of fibers or particles acts equally in resisting strain. So far the theoretical principle of cohesive strength is simple and easily applied. But let us see how the practical agrees. A round bar one inch diameter is as to a square bar one inch in section as .7854 is to one square inch.

EXAMPLE :—A round bar sustains 17 tons, what will a square bar sustain? As .7854 is to one square inch so is 17 tons to 21.645 and *vice versa*, so it is with any other dimensions. Practice and theory unite in stating that the form of all vessels destined to sustain very high pressures should be circular or globula in shape, because with a square or rectangle or other angular form the pressure naturally inclines to a circle by pressing out the flat sides in the direction of a circle up to the point of separation. Let us take a cylindrical boiler—the effect of internal pressure acting equally on its whole surface, if it exceeds the strength of the material, will doubtless rend it apart at some one point, and possibly two opposite points, and force one-half away from the other; if the material was of uniform consistency and strength, we have no reason to suppose a separation at any particular point more than another, except the fact that material, like human beings, is not perfect. But let us try to trace the influence of the pressure to effect a separation, and present proof that there is undoubtedly double the strain on the seams of a boiler running lengthwise, as to the strain transversely. Suppose the whole shell to be filled with solid matter except a thin film for fluid pressure in the middle running the whole length of the boiler and exerting a pressure on every point of the flat sides of the solid portion exposed to it, we should involve no change in the conditions because the two opposite sides of the circumference that terminate the film of fluid would have to resist exactly the same bursting strain as though the rest of the casing were filled with fluid instead of solid matter. And as this section of fluid would apply at any part of the length of the boiler, let us take a belt of its length one inch wide and trace the effect, which effect would be repeated equally on every such belt one inch wide throughout the whole length of the boiler, provided the material were homogeneous. The bursting pressure on a belt one inch wide is measured by the pressure on a surface having for its length the diameter and one inch wide. Suppose the pressure burst the casing at any one point in the circumference so as to turn one-half around an opposite point as a fulcrum. Then by the well-known principle in mechanics, that a uniform pressure on a lever acting equally at every point of its length has the same effect to turn it around its fulcrum as if it were all collected into one force and acting at the middle point. Therefore we reason that the bursting pressure is equivalent to the whole force on the middle or the radius of the diameter, while the resistance “or cohesive force” of the cylindrical shell acts at the circumference or end of the arm of the lever, and double the distance from the fulcrum. Hence we have the best reason to conclude that the bursting force as resisted at one point of the circumference is just half the pressure on the diameter, or the radius.

To Avoid Tearing Manhole Gaskets.

Put a little white lead on the surface of the gasket which rests on the manhole plate and chalk the other surface heavily and also the part of the manhole frame with which it comes into contact. Upon opening the boiler afterwards the gasket will generally be found to adhere firmly to the plate and to separate from the frame without tearing.

The centre of pressure of a body of water is at two-thirds of the depth from the surface. To find the pressure in pounds per square inch of a column of water, multiply the height of the column by .434; every foot elevation is called, (approximately) equal to one-half pound pressure per square inch.

BOILERS.

Force required to punch a hole in wrought iron, is the circumference of the hole multiplied by the thickness—and the resisting force equal to the tensile strength of the plate having a sectional area equal to the surface of separation. What is the force required to punch a circular hole 1 inch diameter through a plate $\frac{3}{4}$ inch thick? The circumference of 1 inch diameter is $3.1416 \times \frac{3}{4} = 2.3562$ square inches, the area of surface of separation. By experiment it is found that the weight to tear asunder a bar of iron 1 square inch sectional area is 26 tons gross—near 58,240 lbs.; therefore we multiply 2.3562 square inches by 26 tons, which gives 61.2612 tons, this $\times 2240$ lbs. = 137,225 lbs. From this we infer that all rivet holes in boilers should be drilled, and the extra cost should not forbid the best methods in so important a factor of power and product.

Find the mean pressure without an indicator, also the horse power of an engine whose cylinder is 25 inches diameter; stroke, 5 feet; cut-off $\frac{3}{10}$ and an assumed clearance about $3\frac{1}{2}$ per cent.; 50 revolutions per minute; 72 lbs. initial pressure in steam chest; counter pressure $1\frac{1}{2}$ lbs. above atmosphere.

Operation, $25^2 \times .7854 = 490.875$. Multiply this by piston speed, $50 \times 10 = 500$ feet per minute = $245437.500 \div 33.00 = 7.437$ factor for one lb. of steam, this multiplied by the mean pressure when found will be the dividend to the divisor $33.000 \frac{A \times S}{33,000}$

Then the area 490.875×60 inch stroke = 29452.5 cubic inches piston displacement. Then suppose the clearance, including the piston clearance, also the area of steam and exhaust parts = 981.75 cubic inches (equal to $4\frac{1}{2}$ gallons of water); this is contained 30 times in the piston displacement, and 30 in 100 is 3.33 plus or 03.33 per cent., and 60 inches $\times$ by 03.33 = 1.998, say 2 inches. Then $\frac{3}{10}$ of 60 inches is 18 inches, point of cut off.

Then by rule. Divide length of stroke of piston, 60 inches added to the clearance in the cylinder at one end, by the length of the stroke at which the steam is cut off added to the clearance at that end, and the quotient will express the relative expansion. Then find in the table of logarithms the number nearest to that of the quotient, to which add one; the sum is the ratio of gain. Then multiply this ratio by the pressure of steam added to the pressure of the atmosphere, which at the level of the sea is 14.7 "absolute," as it enters the cylinder. Then divide the product by the relative expansion, and the quotient will be the mean pressure on the piston, minus the absolute back pressure.

Then to the length of stroke, 60 inches, add 2 = 62 inches and to 18, the point of cut off, add 2 = 20 inches. Then divide 62 by 20 = 3.1, and the logarithm of 3.1 is 1.131, to which add 1 = 2.131. Then to 72 lbs initial pressure add the atmospheric pressure 14.7 = 86.7; multiply this by 2.131 = 184.7577. Divide this by the relative expansion 3.1 = 59.599, deduct the absolute back pressure $14.7 - 1\frac{1}{2} = 16.2$, the result is 43.399 lbs. ($43\frac{3}{4}$) mean pressure required. Then multiply the above factor for 1 lb. of steam, 7.437 by 43.399 = 322.75 horse power ($322\frac{3}{4}$ indicated). When the mean pressure "as per card" is known, multiply the area by speed of piston per minute and the mean pressure, then divide the result by 33,000; the quotient will be the horse power. When many cards are taken under varied conditions of load, the factor of the engine for 1 lb. of steam should be "posted up" ready to multiply by the different pressures.

The differences that exist for the calculation of the safe working pressures so far as the diminished strength is concerned by the punched holes, and the different percentages between single and double riveting, are a source of confusion to the student in steam engineering who would much prefer a single factor that could be applied to all new boilers. And we know no reason why such single factor of safety should not exist. In reviewing the past forty years, and an eye witness, first as a rivet heater, thence through the various grades that prevail in the profession, and with the progress made both in the material and workmanship, I think it time to adopt rules more in accord with the progress of the times, and strike from the record the percentages of Sir Wm. Fairbairn with all credit due him.

To ILLUSTRATE.—A boiler 48 inches diameter, plate $\frac{3}{8}$ thick; heads double the thickness; tensile strength of plate, 65,000 lbs. per square inch of section, what is the bursting pressure, and safe working pressure in accordance with the rule adopted by the super-vising inspectors of the United States?

EXAMPLE 1.— $\frac{65,000 \times 3.8}{24} = 1015.625$ lbs. bursting pressure without joints; divide this by $\frac{1}{2} = 169.271$ safe working pressure. Again $\frac{T \times S}{24 \times 8 \times 6} = 169.271$.

EXAMPLE 2.— $\frac{65,000 \times 3 \times .70}{24 \times 8 \times 5} = \frac{142.1875}{D-R}$ lbs.

EXAMPLE 3.— $\frac{65,000 \times 3 \times .56}{24 \times 8 \times 5} = \frac{113.75}{S-R}$ lbs. per square inch.

To Ascertain the Safe Working Pressure on a Boiler.

Multiply twice the thickness of the shell by the tensile strength, and divide the product by the diameter of the shell in inches.

To Find the Strength of a Boiler.

RULE :—Multiply the tensile strength of the plate in lbs. by the thickness in decimals of an inch; divide by diameter of the boiler in inches and multiply the product by 2: the answer will be the bursting pressure.

EXAMPLE :—If a boiler is 48 inches in diameter and made of $\frac{1}{4}$ inch steel, having a tensile (or tearing) strength of 60.000 to the square inch, then—

$$\begin{array}{r}
 \text{Thickness,} \quad 60.000 \\
 \quad \quad \quad .25 \\
 \hline
 3000.00 \\
 12000.0 \\
 \text{Diameter, } 48 \overline{) 15.000.00} \quad (312.5 \\
 \quad \quad \quad 144 \quad \quad \quad \times 2 \\
 \quad \quad \quad \hline
 \quad \quad \quad 60 \quad \quad \quad 625 \text{ lbs. strength to the} \\
 \quad \quad \quad 48 \quad \quad \quad \text{square inch.} \\
 \quad \quad \quad \hline
 \quad \quad \quad 120 \\
 \quad \quad \quad 96 \\
 \quad \quad \quad \hline
 \quad \quad \quad 240 \\
 \quad \quad \quad 240 \\
 \quad \quad \quad \hline
 \quad \quad \quad 0
 \end{array}$$

NOTE.—In practice, if the boiler is single riveted, $\frac{1}{3}$ only of the above would be allowed as safe, or $104\frac{1}{10}$ lbs. on the steam gauge. With double rows of rivets, and rivet holes drilled instead of punched, a working pressure of 125 lbs. would be allowed.

EXAMPLE :—If a boiler is 44 inches in diameter and made of $\frac{9}{32}$ inch steel, having a tensile (or tearing) strength of 60.000 to the square inch, then—

.32) 9000 (.281

$$\begin{array}{r}
 64 \\
 \hline
 260 \\
 256 \\
 \hline
 40 \\
 32 \\
 \hline
 8
 \end{array}$$

$$\begin{array}{r}
 \text{Thickness,} \quad .281 \\
 \quad \quad \quad 60.000 \\
 \text{Diameter, } 44 \overline{) 16860.000} \\
 \quad \quad \quad 132 \quad 383 \\
 \quad \quad \quad \hline
 \quad \quad \quad 366 \\
 \quad \quad \quad 352 \\
 \quad \quad \quad \hline
 \quad \quad \quad 140 \\
 \quad \quad \quad 132
 \end{array}$$

$$\begin{array}{r}
 383 \\
 2 \\
 \hline
 6 \overline{) 766} \text{ strength to square inch.} \\
 127\frac{2}{3}
 \end{array}$$

Safe load on boiler,

Weights of Boiler Iron.

A cubic foot of iron weighs 480 lbs., consequently a piece one foot square and one inch thick weighs one-twelfth of 480 lbs., or 40 lbs., and a plate one foot square and one-sixteenth of an inch thick weighs $2\frac{1}{2}$ lbs., consequently we have the following rule: Multiply the thickness in sixteenths of an inch by $2\frac{1}{2}$; the result is the weight in pounds per square foot.

$5 \times 2\frac{1}{2}$ lbs. = $12\frac{1}{2}$ lbs., the weight required.

3.6 cubic inches weigh 1 lb.

To find the weight per foot in length of round iron: Take the diameter in quarter inches, square it and divide by 6. Example: What is the weight per foot of 2 inch round iron?

2 inch = 8 quarter inches.

8 squared = $8 \times 8 = 64$.

64 divided by 6 = $10\frac{2}{3}$ lbs., the required weight.

Wrought Iron Welded Pipe.

One inch and below are butt-welded and proved to 300 lbs. per square inch, hydraulic pressure.

$1\frac{1}{4}$ inch and above are lap-welded and proved to 500 lbs. per square inch, hydraulic pressure.

To Find the Horse Power of a Boiler.

Horse power at the best is but a relative term, used for convenience, and this is especially the case where it is applied to boilers.

It is found by dividing the square feet of heating surface in a return tubular boiler by 15 or that of a flue or cylinder boiler by 12.

The heating surface of a return tubular boiler consists of the superficial area of all the tubes and the bottom half of the shell, but in a flue boiler the superficial area of five-eighths of the shell and that of the flues is taken as heating surface. (If something more accurate is required, the area of the heads below the water line, less the area of the tube holes should be added).

EXAMPLE.—A horizontal tubular boiler is 4 feet in diameter by 13 feet in length with 45 tubes 3 inches in diameter by 13 feet long. What is its horse power?

If of 4 feet in diameter it will have 12,566 feet circumference, half of which is 6.28 feet. This multiplied by 13 feet, gives 81.64 feet for half the shell area. Each tube has a diameter of 3 inches, giving 9 42 inches for its circumference, this multiplied by 156 (its length in inches) gives 1469.5 inches or (divided by 144) 10.2 square feet for the area of one tube. Multiplying by 45 we have 469 square feet as the area of all the tubes, this added to 81.64 gives 550.94 square feet for the area or heating surface. Dividing this by 15 we have for its horse power 36.7.

To Find the Horse Power of an Engine.

Multiply the area of the piston in square inches (A) by the average pressure of steam exerted on the piston throughout its stroke, (called the mean effective pressure (B); multiply this result by the number of feet the piston travels per minute (C) and divide by 33,000, and the answer will be the horse power.

(A) the area of the piston in square inches is found by multiplying the square of its diameter by .7854.

(B) the pressure per square inch throughout the stroke can only be accurately determined by the use of the indicator. An approximate result may be obtained without it by using the boiler pressure and deducting 60% for engine below 20 h. p., 50% for those up to 100 h. p., 40% for those above.

If the point of cut-off of the engine is known (that part of the stroke which has been gone over when the steam valve closes) the mean effective pressure may be quite accurately ascertained by the following table at

$\frac{1}{2}$ stroke = the boiler pressure $\times .597$	$\frac{3}{8}$ stroke = the boiler pressure $\times .919$
$\frac{1}{4}$ " " " " " " $.670$	$\frac{1}{2}$ " " " " " " $.937$
$\frac{3}{8}$ " " " " " " $.740$	$\frac{3}{4}$ " " " " " " $.966$
$\frac{1}{2}$ " " " " " " $.847$	$\frac{7}{8}$ " " " " " " $.992$

(C) the piston speed or travel is found by multiplying twice the length of the stroke in feet, by the number of revolutions per minute.

An easy way to remember this rule is to use the following equation: P. A. (Piston Area) P. S. (Piston Speed) M. E. P. (Mean Effective Pressure), H. P. (Horse Power).

$$\frac{H. A. \times P. S. \times M. E. P.}{33,000} = H. P.$$

Grate Areas, and to Find Centre of Gravity.

To find the area of safety valve for a certain grate area:

Formula— $\frac{A=22.5 \times G}{P+8.62}$ = area of valve. (A, area; G, grate area; P, pressure.)

Grate area, 36 square feet $\times 22.5 = 810 = 9.14$ square inches valve.

Pressure on boiler, 80 lbs. $+ 8.62 = 88.62$.

Grate area 42 square feet, press. 80 lbs.; then $22.5 \times 42 = 945.00 = 10.66$ area of valve.

And $80 \text{ lbs.} + 8.62 = 88.62$

What is the weight of a safety valve lever or any other lever? Multiply width by the thickness, the product by the length, and divide by .2816, the weight of a cubic inch.

A lever 2 inches wide, $\frac{1}{4}$ inch thick, and 36 inches long, what is its weight? $2 \times .5 = 1.0 \times 36 = 36$ cubic inches $\times .2816 = 10.137$ lbs., or 10 lbs. $2\frac{1}{2}$ ozs.

To find the centre of gravity of a tapered lever, weigh the two ends separately, the opposite end resting: thus a lever is 36 inches long, weighs at large end 10 lbs., at small end 4 lbs. $\frac{4 \times 36}{10} = 14\frac{2}{5}$ inches centre of gravity from fulcrum.

Again, divide length of lever by 2, and by 6 multiply the latter quotient by width of large end of lever, less the width of small end, divided by width of large end, plus the width of small end; subtract this from the first quotient and the remainder will be the distance of centre of gravity from fulc. A lever is 4 feet long 3 inches wide at one end and 2 inches at the other, and of uniform thickness $\frac{1}{8}$ inches $= 24$, and $\frac{1}{8}$ inches $= 8$. Then 2 inches divided by 3 inches, the large end $= .666$, to which add the width of small end making 2.666; subtract this from large end 3 inches, will leave .334; multiply this by 8, equals 2.672, this from 24 inches $= 21.328$ or $21\frac{5}{16}$ from fulc. to centre of gravity.

PROPORTION OF SAFETY VALVE AREA TO GRATE SURFACE.

UNITED STATES RULE.—Allow one square inch of area of valve for two square feet of area of grate in the case of a common lever valve.

Allow one square inch of area of valve for every three square feet of area of grate in spring loaded safety valves.

ENGLISH RULE.—For boilers with natural draft allow half a square inch of area of safety valve for each square foot of grate surface.

PROFESSOR RANKIN'S RULE.—Allow a valve $\frac{1}{1000}$ th of an inch for each pound of water evaporated per hour.

FRENCH RULE.—Adopted by the Philadelphia Boiler Inspection Department.

1. Multiply the area of the grate in square feet by the number 22.5.
2. Add the number 8.62 to the pressure that is allowed per square inch.
3. Divide (1) by (2) and the quotient is the area of the valve in square inches.

Safety valves are of three kinds, known as "common lever," "dead weight," and "spring." The common lever valve is in more general use than the others, but it is imperfect in its action as it does not always seat itself until the steam pressure is reduced to several lbs. below what it is set to blow at.

To find the weight to be placed on the end of a safety valve lever :

1. Square the diameter of valve and multiply by .7854, which will give the area.
2. Multiply the area by the pressure per square inch.
3. From the product take the effective weight of the valve and stem.
4. Multiply the remainder by the "distance from the fulcrum to the valve."
5. Then subtract the effective weight of the lever.
6. Then divide by the distance from the fulcrum to the end of lever (or centre of weight).

EXAMPLE :—Required, the weight to be placed on the end of a safety valve lever to be equal to 20 lbs. per square inch on the valve, the diameter of valve being 5 inches, the distance from the fulcrum to the valve being 6 inches, and from the centre of weight to valve 10 inches; the effective weight of the lever is 80 lbs., and the weight of the valve and stem is 12 lbs.

.7854	
25	diameter squared.
3.9270	
15.708	
19.6350	area of valve.
20	lbs. pressure per square inch.
392.7000	total pressure on valve.
12.	weight of valve and stem.
380.7	
6	distance from fulcrum to valve.
2284.2	
80.	effective weight of lever.
4)2204.2	} divide by 16 inches the full length of lever.
4) 551.05	
137.7625	

Answer : Weight required, 137 $\frac{1}{4}$ lbs., nearly.

Economy of Engines.

Steam engines vary in economy, requiring the evaporation of from 15 to 60 pounds of water per horse power per hour, depending upon the compounding and general economy of the machine.

Boilers well set, with good draught will evaporate from 7 to 10 pounds of water per pound of first-class coal though the average result is from 30 to 60 per cent. below this.

One square foot of grate surface will consume on an average 12 pounds of coal per hour. The heating surface in a boiler should be about 30 times the grate surface. By referring to the above and noting the amount of feed water evaporation required by an engine, the size of a boiler necessary to furnish steam for it may be determined.

Rule for Fixing the Proper Sectional Area of a Chimney of a Land Boiler when its Height is Determined.

RULE :—Multiply the number of pounds of coal consumed under the boiler per hour by 12 and divide the product by the square root of the height of the chimney in feet ; the quotient is the proper area of the chimney in square inches at the smallest part.

EXAMPLE :—What is the proper sectional area of a factory chimney 80 feet high and with a consumption of coal in the furnace of 300 lbs. per hour?

Here $300 \times 12 = 3600$ and divide by 9 the square root of the height nearly, we get 400, which is the proper sectional area of the chimney in square inches ; if therefore the chimney be square it will measure 20 inches each way.

Rule for fixing the proper height of the chimney : Multiply the number of pounds of coal consumed under the boiler per hour by 12 and divide the product by the sectional area of the chimney in square inches ; square the quotient thus obtained which will give the proper height of the chimney in feet.

EXAMPLE :—What is the proper height in feet of the chimney of a boiler which burns 300 lbs. of coal per hour, the sectional area of the chimney being 400 square inches?

Here $300 \times 12 = 3600$ which divided by 400 (the sectional area) = 9, the square of which is 81 feet, and this is the proper height in feet.

To determine the dimensions of the cold water pump :

RULE :—Multiply the square of the diameter of the cylinder in inches by the length of the stroke in feet and divide the product by 4.400 ; the quotient is the proper capacity of cold water pump in cubic feet.

EXAMPLE :—What is the proper capacity of the cold water pump in an engine having a 60 inch cylinder and a $5\frac{1}{2}$ ft. stroke?

Here $60 \times 60 = 3.600$, which multiplied by $5\frac{1}{2}$ is 19.800, and this divided by 4.400 is 4.5, which is the proper capacity of the cold water pump in cubic feet.

Fly-wheel.—Find the sectional area of the fly-wheel rim as follows :

RULE :—Multiply 44.000 times the length of the stroke in feet by the square of the diameter of the cylinders in inches, and divide the product by the square of the number of revolutions per minute multiplied by the cube of the diameter of the fly-wheel in feet. The resulting number will be the proper sectional area of the fly-wheel rim in square inches.

EXAMPLE :—What will be the proper sectional area of the fly-wheel rim in square inches in the case of an engine with a cylinder 24 inches diameter and 5 feet stroke, the fly wheel being 20 feet diameter?

Here 44.000 multiplied by 5, which is the length of the stroke in feet, is 22.000. The square of the diameter of the cylinder in inches is 576, and $22.000 \times 576 = 126,720,000$. The engine will make about 21 revolutions, the square of which is 441, and the cube of the diameter of the fly-wheel in feet is 8.000, which multiplied by 441 is 3,528,000. Finally, 126,720,000 divided by 3,528,000 is 35.8, which is the proper area in square inches of the section of the fly-wheel rim.

To find the area of the steam pipe leading to each cylinder :

RULE :—Multiply the square of the diameter of the cylinder in inches by the speed of the piston in feet per minute and by the decimal .02, and divide the product by 170 ; the quotient is the proper area of the steam pipe leading to the cylinder in inches.

EXAMPLE :—What is the proper area of the branch steam pipe leading to each cylinder in an engine with a cylinder $74\frac{1}{2}$ inches in diameter and with the piston moving at a speed of 220 feet per minute?

Here $74.5 \times 74.5 = 5,550.25$, which multiplied by 220 = 1,221.055, and this multiplied by .02 = 24.421.1, which divided by 170 = 144 square inches nearly. The diameter of a circle of 144 square inches area is a little over $13\frac{1}{2}$ inches, so that $13\frac{1}{2}$ inches would be the proper internal diameter of each branch steam pipe in such an engine. The main steam pipe will require to have nearly but not quite double the area of each of the branch steam pipes. It would require to have exactly double the area, only the friction in a large pipe is relatively less than in a small one, and as the engines work at right angles, so that one piston is at the end of its stroke when the other is at the beginning and therefore moving slowly, it will follow that when one engine is making the greatest demand for steam the other is making very little, so that the area of the main steam pipe will not require to be as large as if the two engines were making their greatest demand at the same time.

To Glue Leather to Iron.

To glue leather to iron, paint the iron with some kind of lead color, say white lead and lamp black. When dry cover with a cement made as follows : Take the best glue, soak it in cold water until soft, then dissolve in vinegar with a moderate heat ; then add one-third of its bulk of white pine turpentine, thoroughly mix, and by means of the vinegar make it of the proper consistency to be spread with a brush, and apply it while hot ; draw the leather on quickly and press it tightly in place. If a pulley, draw the leather around tightly as possible, lap and clamp.

To Find the Proper Diameter of a Safety Valve that will let off all the Steam from a Low Pressure..

RULE :—Multiply the square of the diameter of the cylinder in inches by the speed of the piston in feet per minute, and divide the product by 14 000 ; the quotient is the proper area of the safety valve in square inches.

EXAMPLE :—What is the diameter of the safety valve of a boiler that supplies an engine with steam having a 64 inch cylinder, and with the piston travelling 220 feet per minute?

Here $64 \times 64 = 4.096$ which multiplied by 220 = 901,120, and this divided by 14,000 = 64.3 which is the proper area of the safety valve in square inches.

To find the proper capacity of the feed pump :

RULE :—Multiply the capacity of the cylinder in cubic inches by the total pressure of the steam in the boiler on each square inch (or by the load on each square inch of the safety valve, plus 15 lbs. on each square inch for the pressure of the atmosphere), and divide the product by 4,000 ; the quotient is the proper capacity of the feed pump in cubic inches when the pump is single acting and the engine is double acting.

EXAMPLE :—What is the proper volume of the working part of the plunger of a locomotive feed pump having cylinders 18 inches diameter and 2 feet stroke, working with a pressure of 85 lbs. above the atmosphere? The area of a circle 18 inches diameter, is 254.5 square inches which multiplied by 24 inches, which is the length of the stroke, gives 6,108 cubic inches, as the capacity of the cylinder. If the steam be 85 lbs. above the atmosphere, then the total pressure must be 100 lbs. per square inch, and $6,108 \times 100 = 610,800$, which divided by 4,000 gives 152.7 as the capacity of the feed pump in cubic inches.

INJECTORS.

The capacities of injectors are denoted by the diameters of their throats in millimeters which is $\frac{1}{1000}$ th of a meter or .0394 inches. No. 4 equals .1576 inches.—*Haswell*.

ILLUSTRATION.—To find the diameter of throat and mean volume of discharge: $.077 - \sqrt{\frac{V}{P}} = d$ $\frac{1}{12.9} a^2 P$ —pressure, V—volume of water in cubic feet per hour, a diameter.

The pressure is 85 lbs. and the volume required per hour is 62 cubic feet. The square root of 85 lbs. is 9.2195, and the volume is 62 cubic feet divided by square root of pressure 9.2195 = 6.7357, and the square root of this is $2.595 \times .077 = .1998 \div .0394 = 5.07$ say No. 5 plus, and the square root of the pressure multiplied by 6.7357 = 62.0997 cubic feet of water per hour. The injector, when viewed in the light of economy, is not the equal of a well proportioned pump for boiler feeding, but without a good feed water heater it is the superior of a pump, inasmuch as it will not inject into the boiler cold water, although the heat was taken from and returned to the boiler. It is within the memory of the living that to have advanced the theory upon which the injector acts would have been ample cause for a commission *lunatico inquirendo*. To-day we may view it with surprise that so useful, simple and powerful an instrument remained so long unknown to mechanical science, as the primary adjuncts had long been in use in the lapidary, the fire nozzle, the locomotive blast pipe, the bellows, etc. It is a noble adjunct in every steam plant. The mechanical press is furnished with a fixed spindle whose function is to concentrate the steam, but the principle of its merit is the combining nozzle which is split from the throat backwards $\frac{1}{4}$ of its length, one-half being united in solid form, the other half hinged to permit freedom of action, and to enlarge or contract the area of opening in accordance with local conditions ; the germ of its power being the velocity of steam at atmospheric pressure flowing into a more or less perfect vacuum, etc.

The mechanical press has contributed very much to a proper understanding of its operation. They are all types of the one family, and resemble each other inwardly and outwardly, though not of equal merit. The parent of all is the Giffard, who doubtless builded better than he knew. The principal causes that enable this useful instrument to return to the boiler the issuing steam with which it operates, "and which could not again return without such device placed between the education of steam and induction of water," is the different relative velocities of steam and water under equal conditions. The decrease in the volume of steam by condensation in the ratio of volume to density at 30 lbs. absolute, 883 to 1, and velocity about 1428 feet per second. In brief, by the combinations utilized in its operation, a superior force is obtained, enabling it not only to overcome its own pressure, but to penetrate a boiler of more than double the pressure of the steam that operates it. By a well-known law in mechanics a momentum, or "impetus," is produced in due proportion to the weight of water multiplied by velocity of steam. The injector which is operated by the exhaust steam of the engine at about 14.7 lbs. absolute, forcing water against a pressure of 80 lbs. "gauge," is but little different from the rest in its construction, is a steam-combining and delivery nozzle, the latter is furnished, etc.

Comparative Efficiency of Different Machines for Raising Water (H²O).

Of the different pumps experimented upon by General Morin, the result of eight experiments made with pumps draining mines showed that the effect utilized 66 per cent. of the power expended. But in these cases there was considerable loss from leakage from the pipes. At the salt works of Drenze the useful effect was 52.3 per cent. of the power expended. In fire-engine pumps employed to deliver the water pumped at a height of from 12 to 20 feet, the proportion of the water delivered to the capacity of the pump was in the pumps of the following makes—Merryweather, Tylor, Perry, Carl-Metz, Letestu, Fland and Perrin, respectively, as follows: .920, .887, .910, .974, .910, .920 and .900, while the percentage of the useful effect relatively with the power expended was 39.7, 39.1, 30.2, 28.7, 27.1, 19.4 and 15.5, respectively. With a higher pressure the efficiency of the whole of the pumps increased, and when employed in throwing water with a spout-pipe the delivery of water relatively with the effective capacity, or space described by the piston, was, when the names are arranged as follows: Carl-Metz, Merryweather, Tylor, Letestu, Perry, Fland, Perrin and Lamoine, respectively, .950, .810, .565, .870, .910, .912, .950 and .900; while the proportion of useful effect, or percentage of work done relatively with the power expended, was 80, 57.3, 54.5, 45.2, 37.8, 33.4, 28.8 and 17.5, in the respective cases. In the membrane pump of M. Brûle the efficiency was found to be 40 to 45 per cent. of the power expended. In the water-works pumps of Ivey, constructed by Cavé, the efficiency was found to be 53 per cent. of the power expended, and in the water-works of St. Onen, by the same maker, 73 per cent. It is desirable that the buckets of the pumps of water-works should move slowly, otherwise the water will go off with considerable velocity, involving a corresponding loss of power. The area through the valves should be half the area of the pump, and the area of the suction and forcing pipes ought to be equal to three-fourths of the area of the body of the pump. The loss of water through the valves before they shut, is, in good pumps, about 10 per cent.

In a chain pump the efficiency was found to be 38 per cent., but in many chain pumps the efficiency is much more than this. The efficiency of the Persian wheel was found to increase very much with the height to which the water was raised. For heights of one yard it was 43 per cent., for two yards 57 per cent., for three yards 63 per cent., for four yards 66 per cent., and for six yards and upwards 70 per cent. of the power consumed. For a wheel of pots the efficiency is 60 per cent., Archimedes screw 65 per cent., scoop wheel with flat boards moving in a circular channel 70 per cent., improved bucket wheel 82 per cent., and tympan wheel, or, as it is sometimes called, Uirtz's Zwisch machine 88 per cent. This machine should dip at least a foot into the water to give the best results. In the belt pump the efficiency was found to be 43 per cent., in Appold's centrifugal pump 65 per cent., in the centrifugal pump with inclined vanes 42 per cent., and with radial vanes 24 per cent. In Gwynn's pump the efficiency was 30 per cent.

In the Archimedes screw the diameter is usually one-twelfth of the length, and the diameter of the newel or central drum should be one-third of the diameter of the screw. It ought to have at least three convolutions, and the line traced by the screw on the enveloping cylinder should have an angle of 67° to 70° with the axis. The axis itself should make an angle of from 30° to 45° with the horizon. There is a sensible advantage obtained from working hand pumps by a crank instead of a lever.

Table showing the Pressure of Water at Different Elevations.

Feet Head.	Equals Pressure per Square Inch.	Feet Head.	Equals Pressure per Square Inch.	Feet Head.	Equals Pressure per Square Inch.	Feet Head.	Equals Pressure per Square Inch.	Feet Head.	Equals Pressure per Square Inch.	Feet Head.	Equals Pressure per Square Inch.
1.....	.43	65....	28.15	130....	56.31	195..	84.47	260....	112.62	350....	151.61
5.....	2.16	70....	30.32	135....	58.48	200...	86.63	265....	114.79	360....	155.94
10.....	4.33	75....	32.48	140....	60.64	205...	88.80	270....	116.96	370....	160.27
15.....	6.49	80....	34.65	145....	62.81	210...	90.96	275...	119.12	380....	164.61
20.....	8.66	85....	36.82	150....	64.97	215...	93.14	280...	121.29	390....	168.94
25.....	10.82	90...	38.98	155....	67.14	220...	95.30	285...	123.45	400....	173.27
30.....	12.99	95....	41.15	160....	69.31	225...	97.49	290....	125.62	500....	216.58
35.....	15.16	100...	43.31	165....	71.47	230...	99.63	295....	127.78	600...	259.90
40....	17.32	105....	45.48	170....	73.64	235...	101.79	300....	129.95	700....	303.22
45.....	19.49	110...	47.64	175....	75.80	240...	103.96	310...	134.28	800....	346.54
50.....	21.65	115....	49.81	180....	77.97	245...	106.13	320....	138.62	900....	389.86
55.....	23.82	120....	51.98	185....	80.14	250...	108.29	330....	142.95	1000...	433.18
60.....	25.99	125....	54.15	190....	82.30	255...	110.46	340....	147.28		

Table showing Dimensions and Capacity of Standard Water Tanks.

DIAMETER.		HEIGHT.	CAPACITY.
6 Feet,	Inches.	5 Feet, 11 Inches.	1,000 Galls.
8 "	6 "	5 "	2,000 "
10 "	3 "	5 "	3,000 "
11 "	9 "	5 "	4,000 "
13 "	3 "	5 "	5,000 "
8 "	3 "	7 "	2,500 "
10 "	3 "	7 "	4,000 "
12 "	5 "	7 "	6,000 "
10 "	4 "	9 "	5,000 "
12 "	5 "	9 "	7,500 "
11 "	10 "	11 "	8,000 "
13 "	3 "	11 "	10,000 "
16 "	" "	11 "	15,000 "
18 "	3 "	11 "	20,000 "
20 "	2 "	11 "	25,000 "
28 "	6 "	11 "	50,000 "

TABLE OF AMERICAN COALS.

COAL.			THEORETICAL VALUE.	
State	Kind of Coal.	Per Cent of Ash.	In Heat. Units per Pound.	In Pounds of Water Evaporation.
Pennsylvania,	Anthracite,	3.49	14.199	14.70
"	"	6.13	13.535	14.01
"	"	2.90	14.221	14.72
"	Cannel,	15.02	13.143	13.60
"	Connelsville,	6.50	13.368	13.84
"	Semi bituminous,	10.77	13.155	13.62
"	Stone's Gas,	5.00	14.021	14.51
"	Youghiogeny,	5.60	14.265	14.76
"	Brown,	9.50	12.324	12.75
Kentucky,	Caking,	2.75	14.391	14.89
"	Cannel,	2.00	15.198	16.76
"	Cannel,	14.80	13.360	13.84
"	Lignite,	7.00	9.326	9.65
Illinois,	Bureau Co.,	5.20	13.025	13.48
"	Mercer Co.,	5.60	13.123	13.58
"	Montauk,	5.50	12.659	13.10
Indiana,	Block,	2.50	13.588	14.38
"	Caking,	5.66	14.146	14.64
"	Cannel,	6.00	13.097	13.56
Maryland,	Cumberland,	13.98	12.226	12.65
Arkansas,	Lignite,	5.00	9.215	9.54
Colorado,	"	9.25	13.562	14.04
"	"	4.50	13.866	14.35
Texas,	"	4.50	12.962	13.41
Washington,	"	3.40	11.551	11.96
Pennsylvania,	Petroleum,	....	20.746	21.47

Air Spaces Between Grates.

Lehigh Pea Coal		$\frac{1}{4}$ of an inch.
Schuylkill Pea		" "
Lehigh Chestnut Coal		" "
" Stove		" "
" Broken		" "
Cumberland	"	" "
Wood		$\frac{3}{4}$ to 1
Sawdust		$\frac{3}{16}$ to $\frac{1}{4}$

To find pressure in pounds per square inch of a column of water: Multiply the height of the column in feet by .434.

Every foot of elevation is called (approximately) equal to one-half pound pressure per square inch.

Testing Coal to Determine its Fuel Value.

Mr. Eckley B. Cox, President of the Society of Mechanical Engineers, in his address at one of the meetings of that organization referred to the subject of testing coal in a manner to give large consumers a practical idea of its value as a fuel. The following extracts from his remarks are interesting.

PRICES AND SIZES.—In the early days of mining all sizes below stove coal were considered of no value, and chestnut coal, although used to some extent at the collieries for steam purposes, was generally wasted. Finally, it became a domestic coal, and the pea coal took its place for steam purposes. Now pea coal is supplanted by buckwheat coal, and has become a domestic coal, and even buckwheat coal is competing for steam generation with what are called rice and barley coal. These coals are graded on the accompanying scale as to cost and size.

Trade Name of Size.	Wholesale Price at Mines.	Limits of Size.	
		Upper.	Lower.
Chestnut, ...	\$2.75	$\frac{7}{8}$	$\frac{3}{4}$
Pea, ...	1.25	$\frac{3}{4}$, $\frac{5}{8}$	$\frac{1}{2}$
Buckwheat, ...	.75	$\frac{5}{8}$	$\frac{3}{8}$
Rice, ...	.25	$\frac{3}{8}$	$\frac{1}{8}$
Barley, ...	.10	$\frac{1}{4}$	$\frac{1}{8}$

FREIGHTS.—In addition to the saving in first cost, freight rates are less on the smaller sizes. Freight to sidewater is 30 cents a ton less on pea than on the domestic sizes, and 50 cents less on sizes smaller than pea. Originally but little attention was paid to these sizes, and no special preparation of furnace beyond a slight change in grate-bars was made by the parties using them. A large amount of culm was used when it could be obtained cheaply, and it then contained the buckwheat, rice and barley coal; but since these have become marketable, and are taken out, the present culm is of slight value.

LACK OF UNIFORMITY.—As coal only burns on the surface, the sizing is of great value. If not uniform, the smaller particles clog the passages between the larger, and impede combustion. To this lack of uniformity are attributable many failures in the use of these smaller sizes for steam, as well as the lack of uniformity in results. The latter may be due to bad sizing, or to an undue amount of impurities. Their experiments have shown it is the percentage of carbon in small sizes rather than the sizing which determines the amount of water evaporated per pound of coal; but the water evaporated per square foot of heating surface decreases with the size of coal.

DEFINITE PERCENTAGES.—If I was in charge of a large steam plant burning, say, 100,000 tons of rice coal per year, I would try to make a contract which would require the coal to contain not over a certain percentage of water, and not less than a certain percentage of carbon, or, what is practically the same thing for anthracite, not over a certain percentage of ash, and that a certain percentage of the average daily sample of the coal would pass through a mesh of a certain size and over a mesh of another size, and that the coal should not contain more than a certain percentage of dust—dust being what would pass through a mesh of, say, $\frac{1}{16}$ inch in diameter.

DETERMINING COAL VALUES.—The method of determining in a rapid, simple, and effective manner the actual commercial value of small-sized coal, and which required no scientific work except for analysis, was next described. The foundation of it was the obtaining of fair average samples. This was done by taking samples of these four sizes from the loading tips several times a day, and putting each size in a separate bin. After a week, the coal in each bin is thoroughly mixed and quartered down till 30 lbs. is obtained, which is sent to the laboratory. These samples may be used for any of the five following purposes:

1. Determination of size.
2. Determination of the slate.
3. Determination of the ash, involving in some cases an analysis of the ash.
4. Determination of the water.
5. Rapid commercial determination of the specific gravity of the coal.

DETERMINATIONS.—The object of the determination of size is to determine the exact size of coal which makes up the sample, as distinguished from its nominal size. As to determination of slate, in large coal it is easy to determine the percentage of slate by average samples, but in small coal a magnifying glass would be needed. So they resorted to a method depending on the difference in the specific gravity of coal and slate, which in coal increases with the amount of ash the coal proper contains, and also with the amount of bone or slate attached to it.

DETERMINATION OF SPECIFIC GRAVITY.—The specific gravity is measured in a rough way by the following apparatus: A sheet-iron bucket holding 25 lbs., a wash-tub, a Fairbank's market beam scale, and a cylindrical pan, 14 inches in diameter by 7 inches deep, are required. The weighing beam is attached to the post by means of a small crane, which throws it out from the post. The ordinary hook used for suspending material to be weighed carries a yoke, from which the tin pan is suspended by two wires. The bucket is also hung on the same hook. The tub is then filled with water until the tin pan is covered, and the whole is then balanced by means of a weight hung on the outer end of the beam, which



weight remains constant. The poise used for weighing moves along the beam in the ordinary way. The beam is divided into pounds and quarter pounds, each notch representing $\frac{1}{4}$ lb. when the ordinary poise is used. In order to weigh to $\frac{1}{100}$ lb., a little rider made of sheet metal, and of such a weight that each notch represents $\frac{1}{100}$ lb., is used; so that by placing the poise in the notch corresponding to the even pound, which is just less than the actual weight, and then moving the rider until the beam balances, and reading off the number of notches, the actual weight in pounds and $\frac{1}{100}$ lb. is obtained. If, for example, the rider is in the second notch to the right hand of the 10 lb. notch, it would read $\frac{2}{100}$ lb.; that is, the 10 lb. would represent 40 notches, which, with the other two, would make 42.

AVERAGE SPECIFIC GRAVITY.—When the average specific gravity of a shipment of coal is to be determined, specimens are taken from all parts until a fair average sample is obtained. This is spread on a platform and quartered down until the material is reduced to about 20 lbs., which is then put into the bucket. If we know the average specific gravity of the sizes below egg coal from a certain colliery, and their average percentage of ash, by merely getting the specific gravity of the coal in a number of cars, we can determine satisfactorily (we are inclined to think) the percentage of ash by the following formula: $y' = y + (x' - x) \times a$; in which x = the standard specific gravity, y = the standard percentage of ash, x' = the specific gravity of coal determined by our apparatus, y' = the percentage of ash to be determined, a = a constant for coal from same mine.

We have become so thoroughly impressed with the importance of having the specific gravity of all samples of coal which we analyze that, whenever the sample sent to the office is large enough, we obtain the specific gravity in a rough way given above, and find that it adds very materially to the value of the data obtained by analysis.

THE AMOUNT OF MOISTURE.—It seems to me that in all important boiler tests, not only the coal used should be analyzed, and a special determination made of the amount of moisture in the coal when it is actually fired, but also that the ashes should be carefully analyzed. The sample for both the analyses should be obtained by quartering down all the coal to be used, and quartering down all the ashes made.

RELATING TO CLINKERS.—The temperature at which the coal burns, and the composition of the ash. The fact that a coal does not clinker may be due to its impurity; that is to say, the coal may be so impure that it will not make a fire hot enough to melt the ash, although the composition of the ash may be such that were it contained in a pure coal it would melt easily. On the other hand, the coal may clinker because it is very pure and burns at a very high temperature.

METHODS SOMETIMES GUESSES.—The value of the various methods of testing coal as well as the evaporative efficiency of boilers has been questioned for some time. The laboratory test of coals which give what is termed the theoretical value in pounds of water capable of being evaporated per pound of coal may be accepted as mere approximations. In fact, sometimes they are not far removed from guesses.

EQUALLY MISLEADING.—Methods of testing the evaporative efficiency of steam boilers are similarly as approximate and equally misleading. What is termed the "standard" method consists of seeing how long a certain quantity of wood will take to start the fire and get the coal ignited at the start of the test, and then seeing how much coal has been left to burn to ash at the end of the test. Another method is to clean the fire at the beginning of the test and observe how long it will take the fire to recover itself and then toward the end of the test let the fire burn low to about the condition of the fire after cleaning at the beginning of the test. The information, if any, gained at the beginning and ending of such tests are of no earthly use to the steam user. The operations at the starting and finishing destroy any possible claims as to the evaporative value of the coal, because the coal is burned under the most adverse conditions.

A METHOD PROPOSED.—A method recently proposed for testing boilers is: Use an hour or more to get the fire into the very best condition, noting the water evaporated, when the water is being evaporated at a certain rate, that is, horse power, for half an hour or so, and note the quantity and condition of the fire. At that time clean out the ash pits and start the test, weighing in coal and water, and developing not less than the horse power observed at the starting. Continue the test for eight or ten hours and stop the test when the evaporation is the same as at starting, and the condition of the fire should also be about the same. These conditions can be checked by noting the operation for a half hour after stopping the test and comparing it with the half hour previous to starting the test.

THE INFORMATION NEEDED.—The results of such a test give the evaporation of water per hour when the boiler is working at a definite capacity, and the exact amount of coal used per hour when the boiler is working at a definite capacity. Each pound of coal burned has charged to it a definite quantity of water. This is the information the steam users need. It is of little consequence to them how much wood or time it takes to reheat a cooled-down boiler, or to know how much water is evaporated by a lot of half-burned coals after the work is done which coals have usually accumulated on the grate through bad firing—clean out ash pit when test is stopped and weigh refuse. The methods of testing coal and boilers now in vogue need improvements, as they are of little value except for comparison.

Water Requirements for Steam Power.

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

The mean pressure of the atmosphere at tide level is usually estimated at 14.7 lbs. per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inch, or column of water 33.9 feet high. In ordinary practice we recommend Pumps be placed not over 20 feet above water supply, and even nearer, where possible.

To find the capacity of any single-acting cylinder, square the diameter (in inches of the cylinder), multiply this by .7854, and the result (which is the area of the circle of cylinder) by the length of stroke in inches. This gives the capacity in cubic inches per stroke. Multiply this by the number of strokes per minute and divide the product by 231, (the number of cubic inches in a gallon of water). The result will be capacity or gallons of water the cylinder will discharge per minute.

A two-cylinder or double-acting cylinder has double the capacity of a single-acting cylinder.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to $\frac{1}{2}$ lb. pressure per square inch; this allows for ordinary friction.

To find the horse power necessary to elevate water to a given height, multiply the number of gallons per minute by 8.35, weight of one gallon, and this result by total number of feet water is raised (that is, from surface of the water to the highest point to which the water is raised), and you have the power in foot pounds. Divide by 33,000 and you have the horse power. One horse power is equal to about five men. To the theoretical power a liberal allowance for friction, etc., always should be added.

WEIGHT AND CAPACITY OF DIFFERENT STANDARD GALLONS OF WATER.

	Cubic Inches in a Gallon.	Weight of a Gallon in Pounds.	Gallons in Cubic Foot.	Weight of a cubic foot of water, English standard, 62.321 lbs. Avoirdupois.
Imperial or English....	277.274	10.00	6.232102	
United States.....	231	8.33111	7.470519	

A miner's inch is a measure for flow of water, and is an opening 1 inch square in plank, 2 inches thick, under a head of 6 inches of water to upper edge of opening.

Steam Requirements.

A good automatic non-condensing engine requires from 3 to 4 lbs. of coal per horse power per hour, according to the quality of the coal.

An automatic condensing engine requires from $2\frac{1}{4}$ to $3\frac{1}{2}$ lbs. of coal per horse power per hour.

A steam jacketed compound condensing engine of the most improved construction may reduce the consumption of coal as low as $1\frac{3}{4}$ to 2 lbs. of coal per horse power per hour.

The average amount of feed-water required for a good, economical engine, is 30 pounds per indicated horse power per hour; engines of high economy will use less than this amount, and those more wasteful will use more. A high piston speed, together with a high rotative speed, is very desirable, as great power may thus be obtained from moderate sized engines, and also the evil of internal condensation is corrected to a great extent, but these are somewhat limited by practical considerations.

A good condenser increases the economical efficiency of an engine from 25 to 40 per centum, and the amount of injection water required is about 25 times the quantity fed into the boilers.

Table of Decimal Equivalents of 8ths, 16ths, 32ds and 64ths of an Inch.

8ths.		32ds.		64ths.	
$\frac{1}{8}$ = .125	$\frac{1}{32}$ = .03125	$\frac{1}{64}$ = .015625	$\frac{1}{128}$ = .0078125	$\frac{1}{256}$ = .00390625	$\frac{1}{512}$ = .001953125
$\frac{2}{8}$ = .250	$\frac{2}{32}$ = .0625	$\frac{2}{64}$ = .03125	$\frac{2}{128}$ = .015625	$\frac{2}{256}$ = .0078125	$\frac{2}{512}$ = .00390625
$\frac{3}{8}$ = .375	$\frac{3}{32}$ = .09375	$\frac{3}{64}$ = .046875	$\frac{3}{128}$ = .0234375	$\frac{3}{256}$ = .01171875	$\frac{3}{512}$ = .005859375
$\frac{4}{8}$ = .500	$\frac{4}{32}$ = .125	$\frac{4}{64}$ = .0625	$\frac{4}{128}$ = .03125	$\frac{4}{256}$ = .015625	$\frac{4}{512}$ = .0078125
$\frac{5}{8}$ = .625	$\frac{5}{32}$ = .15625	$\frac{5}{64}$ = .078125	$\frac{5}{128}$ = .0390625	$\frac{5}{256}$ = .01953125	$\frac{5}{512}$ = .009765625
$\frac{6}{8}$ = .750	$\frac{6}{32}$ = .1875	$\frac{6}{64}$ = .09375	$\frac{6}{128}$ = .046875	$\frac{6}{256}$ = .0234375	$\frac{6}{512}$ = .01171875
$\frac{7}{8}$ = .875	$\frac{7}{32}$ = .21875	$\frac{7}{64}$ = .109375	$\frac{7}{128}$ = .0546875	$\frac{7}{256}$ = .02734375	$\frac{7}{512}$ = .013671875
$\frac{1}{16}$ = .0625	$\frac{1}{64}$ = .015625	$\frac{1}{256}$ = .00390625	$\frac{1}{512}$ = .001953125	$\frac{1}{1024}$ = .0009765625	$\frac{1}{2048}$ = .00048828125
$\frac{2}{16}$ = .125	$\frac{2}{64}$ = .03125	$\frac{2}{256}$ = .0078125	$\frac{2}{512}$ = .00390625	$\frac{2}{1024}$ = .001953125	$\frac{2}{2048}$ = .0009765625
$\frac{3}{16}$ = .1875	$\frac{3}{64}$ = .046875	$\frac{3}{256}$ = .01171875	$\frac{3}{512}$ = .005859375	$\frac{3}{1024}$ = .0029296875	$\frac{3}{2048}$ = .00146484375
$\frac{4}{16}$ = .250	$\frac{4}{64}$ = .0625	$\frac{4}{256}$ = .015625	$\frac{4}{512}$ = .0078125	$\frac{4}{1024}$ = .00390625	$\frac{4}{2048}$ = .001953125
$\frac{5}{16}$ = .3125	$\frac{5}{64}$ = .078125	$\frac{5}{256}$ = .01953125	$\frac{5}{512}$ = .009765625	$\frac{5}{1024}$ = .0048828125	$\frac{5}{2048}$ = .00244140625
$\frac{6}{16}$ = .375	$\frac{6}{64}$ = .09375	$\frac{6}{256}$ = .0234375	$\frac{6}{512}$ = .01171875	$\frac{6}{1024}$ = .005859375	$\frac{6}{2048}$ = .0029296875
$\frac{7}{16}$ = .4375	$\frac{7}{64}$ = .109375	$\frac{7}{256}$ = .02734375	$\frac{7}{512}$ = .013671875	$\frac{7}{1024}$ = .0068359375	$\frac{7}{2048}$ = .00341796875

Points about Steam Pipes.

Extract from a paper on Steam Piping and Efficiency of Steam Plants. By WILLIAM A. PIKE, of the American Society of Mechanical Engineers.

POINTS IN DESIGN.—The following are, perhaps, the points that should be most particularly looked out for in the design of a system of piping :

(1) The piping and accessories should be so arranged that practically dry steam shall always be delivered to the engine.

(2) The steam should reach the engine with very little "drop" in pressure.

(3) The piping should be so planned and valves so placed that water cannot under any circumstances collect anywhere, except in places especially arranged for that purpose.

(4) Wherever practicable, and especially where more than one engine is supplied from one battery of boilers, the piping and valves should be arranged so that in case of accident to any part, it can be shut off without shutting down the whole plant.

FALSE ECONOMY.—The first requirement given above, viz : that the steam should reach the engine dry, is one often neglected, and the writer has in mind plans of considerable magnitude where absolutely no provision is made for drawing off condensed or entrained water except through the engine itself, and the not uncommon cases of broken cylinder heads and pistons testify as to the effect of such designs. In these days of efficient pipe coverings, of separators, steam loops and traps, there is no excuse, but false economy, for allowing water to reach the engine.

(2) Steam should reach the engine with but little drop in pressure. The effect that an improper arrangement of piping has on the pressure with which the steam reaches the engine is probably not as well known as it should be.

(3) The danger that may arise from having piping and valves so arranged that water can collect anywhere except in places specially provided.

(4) The necessity of arranging piping so that in case of accident only a part of the plant need be shut down needs no argument, as the loss and annoyance due to shutting down a large plant, especially one on which the public in any way depends, as in the case of a lighting or street-railway plant, is much greater than the expense involved in making such a thing impossible.

DESIGNS OF PIPING NECESSARY.—The necessity of properly designed and arranged systems of pipes is only in recent years being recognized. Any system of steam piping should be designed and laid out previous to erection. Pipe systems to be satisfactory cannot be put up according to thumb rule. Instructions to Bill or Tom to connect boiler to engine with 6 inch pipe should never again be heard of. Plans, elevations and details of pipe systems should be made with as much care as similar drawings of engines, boilers and buildings, if not more.

STEAM EXTRACTION.—Independent of a main separator or steam extractor, a steam extractor should be placed on vertical pipes near each engine and pump. The necessary traps should be used so that there will be no waste in the sewer, as the water of condensation from all points should be returned into the feed water supply or directly into the boiler.

STORAGE OR CONVEYER.—By the proper proportioning and arrangement of pipes the steam pressure at the engine should be practically the same as in the boiler ; that is, the reduction in pressure at the engine should be very small, almost fractional of one pound. Relatively large main pipes with branch pipe openings on upper side of main pipe are one of the means of attaining this result. Uniform pressure branch pipes from main pipe to engine should be considered more in the sense of steam receptacles or storage drums than as mere conveyers of passages for steam from boiler to engine.

When the conditions of the surroundings necessitate complications in the piping, such as dips, drops, extra bends, etc., great care should be taken so as to thoroughly drain all points where water of condensation is liable to collect. Large "pockets" of the same diameter as the pipes should be used with pipes of proper size to convey the water of condensation to the trap. The area of the conveying pipe to trap should be such as to allow some space for scale, as these pipes, if too small, sometime close up in a short time, according to the quality of the water used. If the "pockets" are at the lower end of vertical steam pipes, the depth of the "pockets" should be greater than when on the under side of horizontal pipes.

All steam pipes, and, in fact, all pipes between steam pipes, and traps and boilers should be well covered, so as to prevent loss of heat as well as reduce the condensation. As few pipes as possible should be located above the boilers ; the pipe from each boiler should extend beyond the front, back or sides to main steam pipe. High-pressure steam-regulating valves are a desirable adjunct to high pressure steam plants, by means of which a uniform high pressure is continuously maintained on the steam pipes to the engines.

In all large steam plants, so as to be fully prepared for an accidental break-down, the boiler plant and pipe system should be duplicated ; this duplication should be complete and not partial.

FRICTION OF WATER IN PIPES.

Friction loss in pounds pressure per square inch for each 100 feet of length in different size clean iron pipe, discharging given quantities of water per minute.

SIZES OF PIPES.—INSIDE DIAMETER.

Gallons per Minute.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.
5	3.3	0.84	0.31	0.12	0.12	.....	.....	.....	.....	.....	.....	.....
10	13.0	3.16	1.05	0.47	0.12	.....	.....	.....	.....	.....	.....	.....
15	28.7	6.98	2.38	0.97	0.12	.....	.....	.....	.....	.....	.....	.....
20	50.4	12.3	4.07	1.66	0.42	.....	.....	.....	.....	.....	.....	.....
25	78.0	19.0	6.40	2.62	0.91	0.21	0.10	.....	.....	.....	.....	.....
30		27.5	9.15	3.75	0.91	.....	.....	.....	.....	.....	.....	.....
35		37.0	12.4	5.05	1.60	.....	.....	.....	.....	.....	.....	.....
40		48.0	16.1	6.52	1.60	.....	.....	.....	.....	.....	.....	.....
45			20.2	8.15	.....	.....	.....	.....	.....	.....	.....	.....
50			24.9	10.0	2.44	0.81	0.35	0.09	.....	.....	.....	.....
55			29.6	22.4	5.32	1.80	0.74	.....	.....	.....	.....	.....
60			34.1	39.0	9.46	3.20	1.31	0.33	0.05	.....	.....	.....
75			56.1	.....	14.9	4.89	1.99	.....	.....	.....	.....	.....
100					21.2	7.9	2.85	0.69	0.10	.....	.....	.....
125					28.1	9.46	3.85	.....	.....	.....	.....	.....
150					37.5	12.47	5.02	1.22	0.17	0.07	0.03	0.01
175						19.66	7.76	1.89	0.26	0.09	0.04	.....
200						28.06	11.2	2.66	0.37	0.12	0.05	0.02
250							15.2	3.65	0.50	0.16	0.06	.....
300							19.5	4.73	0.65	0.25	0.09	0.04
350							30.8	7.43	0.96	0.32	0.18	0.08
400									2.21	0.53	0.32	0.13
500									3.88	1.40	0.49	0.20
750											0.70	0.39
1000											0.95	0.38
1250											1.23	0.49
1500												
1750												
2000												

TABLE FOR EQUALIZING PIPES.

The size of main pipe is given in the column at the left. The number of branches is given in the line on top, and the proper size of branches is given in the body of the table on the line of each main and beneath the desired number of branches.
In commercial sizes the nominal 1¼-inch pipe is generally over-size. Often as large as 1½. It is safe to call it 1.3 inches, and it is so figured in the table. Exact sizes are given for branch pipes. The designer of the pipe system can thus better select the commercial sizes to be used.

NUMBER OF BRANCHES.

Size of Main Pipe.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 inch.	758	644	574	525	488	459	435	415	398	383	370	358	348	338	330
1¼ "	985	838	747	683	635	597	566	540	518	498	482	468	452	440	428
1½ "	1,14	997	861	788	733	689	653	623	597	575	555	538	522	508	494
2 "	1,32	1,20	1,15	1,05	977	918	870	830	796	766	740	717	696	677	660
2½ "	1,89	1,61	1,44	1,31	1,22	1,15	1,09	1,09	985	958	925	896	870	846	825
3 "	2,27	1,92	1,72	1,58	1,47	1,38	1,31	1,25	1,19	1,15	1,11	1,08	1,04	1,02	989
3½ "	2,65	2,26	2,01	1,84	1,71	1,61	1,53	1,45	1,39	1,34	1,30	1,25	1,22	1,18	1,15
4 "	3,03	2,58	2,30	2,10	1,95	1,84	1,74	1,66	1,59	1,53	1,48	1,43	1,39	1,35	1,32
4½ "	3,41	2,90	2,58	2,36	2,20	2,07	1,96	1,87	1,79	1,72	1,67	1,61	1,57	1,52	1,48
5 "	3,79	3,22	2,87	2,63	2,43	2,30	2,18	2,08	1,99	1,92	1,85	1,79	1,74	1,69	1,65
5½ "	4,15	3,87	3,45	3,15	2,93	2,75	2,61	2,49	2,39	2,30	2,22	2,15	2,09	2,03	1,98
6 "	4,55	4,11	3,63	3,35	3,11	2,93	2,79	2,68	2,59	2,50	2,42	2,34	2,28	2,21	2,16
6½ "	5,30	4,51	4,02	3,68	3,42	3,21	3,05	2,91	2,79	2,69	2,60	2,51	2,44	2,37	2,31
7 "	6,06	5,16	4,59	4,20	3,91	3,67	3,48	3,32	3,18	3,09	2,99	2,87	2,78	2,71	2,64
8 "	6,82	5,80	5,17	4,73	4,40	4,13	3,92	3,74	3,58	3,43	3,33	3,23	3,13	3,04	2,97
9 "	7,58	6,44	5,74	5,25	4,88	4,59	4,35	4,15	3,98	3,83	3,70	3,59	3,48	3,38	3,30
10 "	9,08	7,73	6,89	6,30	5,86	5,51	5,22	4,98	4,78	4,60	4,44	4,30	4,18	4,06	3,96
12 "	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE OF CAPACITY OF PUMPS.

The figures at the extreme right and left of the Table are piston, or plunger, diameters; the line of figures across the top are piston, or plunger, strokes; the figures in the body of the Table are the capacity, or displacement, in gallons, corresponding to a single stroke. To find the capacity, for one revolution, multiply the capacity for a single stroke by one, two, three, or four, for single, duplex, triplex, or quadruplex, single-acting; and by two, four or six double-acting Pumps.

TABLE SHOWING CAPACITY OF PUMPS OF GIVEN DIAMETER AND LENGTH STROKE.

Dia. of Cyl. Ins.	LENGTH OF STROKE IN INCHES, AND CAPACITY PER STROKE IN GALLONS, OF PUMP CYLINDER WITH GIVEN DIAMETER.															Dia. of Cyl. Ins.
	2	3	4	5	6	7	8	9	10	12	14	15	16	18	20	24
1 1/4	.0106	.0150	.0212	.0296	.0319	.0372	.0425	.0478	.0531	.0637	.0743	.0797	.0848	.0955	.1062	.1274
1 1/2	.0128	.0192	.0256	.0321	.0386	.0419	.0513	.0578	.0642	.077	.089	.0963	.1027	.1156	.1280	.1541
1 3/4	.0153	.0229	.0306	.0382	.0459	.0533	.0612	.0688	.0765	.0918	.1071	.1147	.1224	.1377	.1530	.1836
1 7/8	.0208	.0312	.0416	.0521	.0625	.0729	.0833	.0937	.1041	.1249	.1457	.1562	.1666	.1874	.2082	.2499
2	.0272	.0408	.0544	.068	.0816	.0952	.1088	.1224	.136	.1632	.1904	.204	.2176	.2448	.2720	.3264
2 1/4	.0344	.0516	.0688	.086	.1039	.1205	.1377	.1548	.1721	.2093	.241	.258	.2754	.3096	.3442	.4128
2 1/2	.0425	.0637	.085	.1062	.1273	.1487	.17	.1912	.2125	.255	.2975	.3187	.34	.3825	.425	.51
2 3/4	.0514	.0771	.1028	.1285	.1543	.1799	.2057	.2313	.2571	.3085	.3598	.3855	.4114	.4626	.5142	.617
3	.0612	.0918	.1224	.1530	.1836	.2142	.2448	.2754	.306	.3672	.4284	.459	.4896	.5508	.612	.7344
3 1/4	.0718	.1077	.1436	.1795	.2154	.2513	.2872	.3231	.3594	.4312	.503	.5385	.5748	.6466	.7182	.8624
3 1/2	.0833	.1249	.1666	.2082	.2499	.2915	.3332	.3748	.4165	.4998	.5831	.6247	.6664	.7497	.833	.996
3 3/4	.0956	.1434	.1912	.239	.2868	.3346	.3824	.4302	.478	.5736	.6692	.687	.7648	.8603	.9561	.1147
4	.1088	.1632	.2176	.272	.3264	.3808	.4352	.4896	.544	.6528	.7616	.816	.8704	.9792	.1088	.13056
4 1/4	.1228	.1842	.2456	.307	.3684	.4298	.4912	.5526	.6141	.7368	.8596	.921	.9824	.1105	.1228	.1473
4 1/2	.1377	.2065	.2754	.3442	.4131	.4819	.5508	.6196	.6885	.8262	.9639	.10327	.11016	.12393	.1377	.16224
4 3/4	.1534	.2301	.3068	.3835	.4602	.5369	.6136	.6903	.7671	.9204	.1073	.115	.1227	.1380	.1534	.184
5	.17	.2550	.34	.425	.51	.595	.68	.765	.85	.102	.119	.1275	.136	.153	.17	.204
5 1/4	.1874	.2811	.3748	.4685	.5622	.6559	.7496	.8433	.9371	.1124	.1311	.1405	.1499	.1686	.1874	.2248
5 1/2	.2037	.3083	.4114	.5142	.6171	.7199	.8228	.9256	.10285	.12342	.14399	.15427	.16456	.18513	.2057	.2494
5 3/4	.2248	.3372	.4496	.562	.6744	.7868	.8992	.1011	.1134	.1348	.1573	.1686	.1789	.2022	.2248	.2696
6	.2448	.3672	.4896	.612	.7344	.8568	.9792	.11016	.12240	.14688	.17136	.18362	.19584	.22032	.2448	.2976
6 1/4	.2656	.3984	.5312	.6640	.7968	.9296	.1062	.1195	.1328	.1593	.1859	.2022	.2154	.2386	.2656	.3168
6 1/2	.2872	.4308	.5744	.7182	.8616	.10052	.11488	.12925	.14364	.17963	.20109	.21546	.22982	.25885	.28728	.34473
6 3/4	.3008	.4647	.6196	.7743	.9294	.1084	.1239	.1394	.1549	.1858	.2168	.2323	.2479	.2788	.3098	.3716
7	.3332	.4998	.6664	.833	.9996	.11662	.13328	.14994	.1666	.19992	.23324	.2499	.26656	.29988	.3332	.39984
7 1/4	.4084	.6126	.8168	.1021	.1225	.1429	.1633	.1837	.2042	.245	.2864	.3063	.3268	.3674	.4084	.49
7 1/2	.4332	.6528	.8704	.1088	.13056	.15232	.17408	.19584	.2176	.26112	.30464	.3264	.34816	.39168	.4352	.52924
8	.5508	.8292	.11016	.1377	.16524	.19278	.22032	.24786	.2754	.33048	.38556	.4131	.44064	.50572	.5508	.6696
9	.68	.102	.136	.17	.204	.238	.272	.306	.34	.408	.476	.51	.544	.612	.68	.816
10	.8227	.12341	.16451	.2057	.2464	.2879	.32911	.37258	.4139	.49367	.57593	.61709	.65823	.74051	.82279	.98735
11	.9792	.1468	.19584	.2448	.29376	.34292	.39168	.44064	.4896	.58732	.68544	.7344	.7833	.88128	.9792	.117504
12	.1149	.1723	.2297	.2872	.3445	.4022	.4596	.5170	.5745	.6894	.8042	.8616	.9192	.1034	.1149	.1378
13																
14	.1332	.1998	.2665	.3331	.3997	.4664	.533	.5996	.6663	.7994	.9328	.9983	.1066	.1199	.1332	.1598
15	.1529	.2294	.3059	.3824	.4589	.5354	.6119	.6884	.7649	.9178	.1070	.1147	.1233	.1376	.1529	.1835
16	.174	.261	.348	.435	.522	.609	.696	.783	.8703	.1044	.1218	.1305	.1392	.1566	.1740	.2088
18	.2202	.3303	.4404	.5505	.6606	.7707	.8808	.9909	.1101	.1321	.1541	.1651	.1761	.1981	.2202	.2642
20	.2720	.408	.5440	.68	.816	.952	.1088	.1224	.136	.1632	.1904	.204	.2176	.2448	.272	.3264

TABLE FOR CONVERTING FEET HEAD OF WATER
INTO PRESSURE PER SQUARE INCH.

Feet Head.	Pounds per Square Inch.	Feet Head.	Pounds per Square Inch.
1	43	190	82.29
2	87	200	86.62
3	130	225	97.45
4	173	240	108.27
5	217	275	119.10
6	260	300	129.93
7	303	325	140.75
8	346	350	151.58
9	390	375	162.41
10	433	400	173.24
15	650	500	216.55
20	866	600	259.86
25	1083	700	303.17
30	1299	800	346.47
35	1516	900	389.78
40	1732	1000	433.09
45	1949	.....	.....
50	2165	.....	.....

TABLE FOR CONVERTING PRESSURE PER SQUARE
INCH INTO FEET HEAD OF WATER.

Pounds per Square Inch.	Feet Head.	Pounds per Square Inch.	Feet Head.
1	2.31	55	126.99
2	4.62	60	138.54
3	6.93	65	150.08
4	9.24	70	161.63
5	11.54	75	173.17
6	13.85	80	184.72
7	16.16	85	196.26
8	18.47	90	207.81
9	20.78	95	219.35
10	23.09	100	230.90
15	34.63	110	253.98
20	46.18	120	277.07
25	57.72	130	298.62
30	69.27	140	300.16
35	80.81	150	323.25
40	92.36	160	346.34
45	103.90	170	368.43
50	115.45	170	392.52

TABLE OF THEORETICAL HORSE POWER REQUIRED TO RAISE WATER TO DIFFERENT HEIGHTS.

Feet.	Gallons per Minute.																Feet.
	5	10	15	20	25	30	35	40	45	50	60	75	90	100	125	150	
5	0.06	0.12	0.19	0.25	0.31	0.37	0.44	0.51	0.58	0.65	0.78	0.94	1.12	1.25	1.50	1.87	5
10	0.12	0.25	0.37	0.50	0.62	0.75	0.87	1.00	1.12	1.25	1.50	1.87	2.25	2.50	3.00	3.75	10
15	0.19	0.37	0.56	0.75	0.94	1.12	1.31	1.50	1.69	1.87	2.25	2.81	3.37	3.75	4.50	5.62	15
20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	3.00	3.75	4.50	5.00	6.00	7.50	20
25	0.31	0.62	0.94	1.25	1.56	1.87	2.25	2.62	2.94	3.25	3.94	4.81	5.62	6.25	7.50	9.38	25
30	0.37	0.75	1.12	1.50	1.87	2.25	2.62	3.00	3.37	3.75	4.50	5.62	6.25	7.00	8.44	10.42	30
35	0.44	0.87	1.31	1.75	2.19	2.62	3.06	3.50	3.94	4.37	5.31	6.56	7.29	8.13	9.88	12.25	35
40	0.51	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.50	8.44	9.38	11.25	13.75	40
45	0.58	1.12	1.68	2.25	2.81	3.37	3.94	4.50	5.00	5.62	6.75	8.44	9.38	10.42	12.50	15.62	45
50	0.65	1.25	1.87	2.50	3.12	3.75	4.37	5.00	5.62	6.25	7.50	9.38	10.42	11.56	13.75	17.19	50
60	0.78	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	9.38	11.56	13.75	15.62	18.75	23.44	60
70	0.94	1.87	2.81	3.75	4.69	5.62	6.56	7.50	8.44	9.38	11.56	14.06	16.25	18.75	22.50	28.13	70
80	1.12	2.25	3.37	4.50	5.62	6.75	7.88	9.00	10.13	11.25	13.75	16.25	18.75	21.25	25.00	31.25	80
90	1.31	2.62	3.94	5.25	6.56	7.88	9.24	10.56	11.88	13.25	16.25	19.38	22.50	25.62	30.00	37.50	90
100	1.50	3.00	4.37	5.75	7.13	8.50	9.88	11.25	12.62	14.00	17.19	20.62	24.06	27.50	32.50	40.00	100
125	1.87	3.75	5.62	7.50	9.38	11.25	13.12	15.00	16.88	18.75	22.50	26.88	31.25	35.62	42.50	50.00	125
150	2.25	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50	27.50	32.50	37.50	42.50	50.00	60.00	150
175	2.62	5.25	7.88	10.42	12.88	15.31	17.75	20.19	22.62	25.00	30.62	36.25	41.88	47.50	55.62	66.25	175
200	3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00	27.00	30.00	36.00	42.00	48.00	54.00	63.00	75.00	200
250	3.75	7.50	11.25	15.00	18.75	22.50	26.25	30.00	33.75	37.50	45.00	52.50	60.00	67.50	78.75	93.75	250
300	4.50	9.00	13.50	18.00	22.50	27.00	31.50	36.00	40.50	45.00	54.00	63.00	72.00	81.00	93.75	112.50	300
350	5.25	10.50	15.75	21.00	26.25	31.50	36.75	42.00	47.25	52.50	63.00	73.50	84.00	94.50	108.75	131.25	350
400	6.00	12.00	18.00	24.00	30.00	36.00	42.00	48.00	54.00	60.00	72.00	84.00	96.00	108.00	123.00	148.00	400
450	6.75	13.50	20.25	27.00	33.75	40.50	47.25	54.00	60.75	67.50	81.00	94.50	108.00	121.50	138.00	165.00	450
500	7.50	15.00	22.50	30.00	37.50	45.00	52.50	60.00	67.50	75.00	90.00	105.00	120.00	135.00	153.75	183.75	500

WROUGHT IRON WELDED STEAM, GAS AND WATER PIPE.

1 inch and below, proved to 300 lbs. per square inch hydraulic pressure. 1½ inch and above, proved to 500 lbs. per square inch hydraulic pressure.

TABLE OF STANDARD SIZES AND DIMENSIONS.

Nominal Inside Diameter.	Actual Inside Diameter.	Actual Outside Diameter.	Thick-ness.	Internal Circum-ference.	External Circum-ference.	Length of pipe pr. sq. foot inside surface.	Length of pipe pr. sq. ft. outside surface.	Internal Area.	External Area.	Length of pipe cont'g 1 cubic ft.	Nominal weight per ft. of length.	No. of Threads per inch of Screw.	Contents of one foot in length.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Feet.	Feet.	Sq. In.	Sq. In.	Feet.	Pounds.		Gallons.
1/8	.27	.40	.07	.84	1.27	14.15	9.44	.06	.12	2500.	.24	27	.002
1/4	.36	.54	.08	1.14	1.69	10.50	7.07	.10	.22	1385.	.42	18	.002
3/8	.49	.67	.09	1.55	2.12	7.67	5.65	.19	.35	751.5	.56	18	.005
1/2	.62	.84	.10	1.95	2.65	6.13	4.50	.30	.55	472.4	.84	14	.010
5/8	.82	1.05	.11	2.58	3.29	4.63	3.63	.53	.86	270.	1.12	14	.023
3/4	1.04	1.31	.13	3.29	4.13	3.67	2.90	.86	1.35	166.9	1.67	11½	.040
1	1.38	1.66	.14	4.33	5.21	2.76	2.30	1.49	2.16	96.25	2.24	11½	.063
1¼	1.61	1.90	.14	5.06	5.96	2.37	2.01	2.03	2.83	70.65	2.66	11½	.091
1½	2.06	2.37	.15	6.49	7.46	1.84	1.61	3.35	4.43	42.36	3.61	8	.163
2	2.46	2.87	.20	7.75	9.03	1.54	1.32	4.78	6.49	30.11	5.74	8	.255
2½	3.06	3.50	.21	9.63	10.96	1.24	1.09	7.38	9.62	19.49	7.54	8	.367
3	3.56	4.	.22	11.14	12.56	1.07	.95	9.83	12.56	14.56	9.00	8	.500
3½	4.02	4.50	.23	12.64	14.13	.94	.84	12.73	15.90	11.31	10.66	8	.652
4	4.50	5.00	.24	14.15	15.70	.84	.76	15.93	19.63	9.03	12.34	8	.826
4½	5.04	5.56	.25	15.84	17.47	.75	.67	19.99	24.29	7.20	14.50	8	1.02
5	5.66	6.32	.28	19.05	20.81	.63	.57	28.88	34.47	4.93	18.76	8	1.46
6	7.02	7.92	.30	22.06	23.95	.54	.50	38.73	45.66	3.72	23.27	8	2.00
7	7.98	8.62	.32	25.07	27.09	.47	.44	50.03	58.42	2.88	23.18	8	2.61
8	9.00	9.88	.34	28.27	30.43	.42	.39	63.63	73.71	2.26	33.70	8	3.30
9	10.01	10.75	.36	31.47	33.77	.38	.35	78.83	90.79	1.80	40.06	8	4.08
10	11.	11.75	.37	34.55	36.91	.34	.32	95.03	108.43	1.50	45.	8	4.93
12	12.	12.75	.37	37.70	40.05	.32	.30	113.09	127.67	1.27	49.	8	5.87
13	13.25	14.	.37	41.62	43.98	.29	.27	137.88	153.94	1.04	54.	8	6.89
14	14.25	15.	.37	44.76	47.12	.27	.25	159.48	176.71	.90	58.	8	8.00
15	15.40	16.	.38	48.48	50.26	.25	.24	187.04	201.06	.68	62.	8	9.18
16	16.40	17.	.30	51.52	53.41	.23	.23	211.24	226.98	.66.	66.	8	10.44
17	17.30	18.	.34	54.41	56.55	.22	.21	235.61	254.47	.61	70.	8	11.79

AREA OF CIRCLES FROM 1-64 TO 26 INCHES.

ADVANCING BY AN EIGHTH.

The areas of circles are to each other as the squares of their respective diameters. In other words, doubling the diameter of a pipe or cylinder increases its capacity (area of circle) four times.

Every foot of height in a column of water represents .434 pounds pressure to the square inch; in common practice, however, it is estimated that every foot in height represents one-half pound pressure to the square inch.

A cubic inch of water weighs .03617 lbs. A cubic foot of water weighs 62.46 lbs.

A gallon of water weighs 8.355 lbs. A gallon of water contains 231 cubic inches.

A cubic foot of water contains 1728 cubic inches. A cubic foot of water contains 7.4805 gallons.

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
$\frac{1}{64}$	.000192	5.....	19.635	12.....	113.098	19.....	283.529
$\frac{1}{32}$	.000767	$\frac{1}{8}$	20.629	$\frac{1}{8}$	115.466	$\frac{1}{8}$	287.272
$\frac{1}{16}$	.003068	$\frac{1}{4}$	21.6476	$\frac{1}{4}$	117.859	$\frac{1}{4}$	291.04
$\frac{1}{8}$	.012272	$\frac{3}{8}$	22.6907	$\frac{3}{8}$	120.277	$\frac{3}{8}$	294.832
$\frac{3}{16}$	.027612	$\frac{1}{2}$	23.7583	$\frac{1}{2}$	122.719	$\frac{1}{2}$	298.648
$\frac{1}{4}$	.049087	$\frac{5}{8}$	24.8505	$\frac{5}{8}$	125.185	$\frac{5}{8}$	302.489
$\frac{3}{8}$	.076699	$\frac{3}{4}$	25.9673	$\frac{3}{4}$	127.677	$\frac{3}{4}$	306.355
$\frac{1}{2}$	.110447	$\frac{7}{8}$	27.1086	$\frac{7}{8}$	130.192	$\frac{7}{8}$	310.245
$\frac{5}{8}$	.15033	6.....	28.2744	13.....	132.733	20.....	314.16
$\frac{3}{4}$	.19635	$\frac{1}{8}$	29.4648	$\frac{1}{8}$	135.297	$\frac{1}{8}$	318.099
$\frac{1}{2}$	.248505	$\frac{1}{4}$	30.6797	$\frac{1}{4}$	137.887	$\frac{1}{4}$	322.063
$\frac{3}{8}$	.306796	$\frac{3}{8}$	31.9191	$\frac{3}{8}$	140.501	$\frac{3}{8}$	326.051
$\frac{1}{4}$	.371224	$\frac{1}{2}$	33.1831	$\frac{1}{2}$	143.139	$\frac{1}{2}$	330.064
$\frac{3}{16}$	.441787	$\frac{5}{8}$	34.4717	$\frac{5}{8}$	145.802	$\frac{5}{8}$	334.102
$\frac{1}{8}$	.518487	$\frac{3}{4}$	35.7848	$\frac{3}{4}$	148.49	$\frac{3}{4}$	338.164
$\frac{3}{16}$	.601322	$\frac{7}{8}$	37.1224	$\frac{7}{8}$	151.202	$\frac{7}{8}$	342.25
$\frac{1}{4}$	.690292	7.....	38.4846	14.....	153.938	21.....	346.361
1.....	.7854	$\frac{1}{8}$	39.8713	$\frac{1}{8}$	156.7	$\frac{1}{8}$	350.497
$\frac{1}{8}$	.99402	$\frac{1}{4}$	41.2826	$\frac{1}{4}$	159.485	$\frac{1}{4}$	354.657
$\frac{1}{4}$	1.2272	$\frac{3}{8}$	42.7184	$\frac{3}{8}$	162.296	$\frac{3}{8}$	358.842
$\frac{3}{8}$	1.4849	$\frac{1}{2}$	44.1787	$\frac{1}{2}$	165.13	$\frac{1}{2}$	363.051
$\frac{1}{2}$	1.7671	$\frac{5}{8}$	45.6636	$\frac{5}{8}$	167.99	$\frac{5}{8}$	367.285
$\frac{3}{4}$	2.0739	$\frac{3}{4}$	47.1731	$\frac{3}{4}$	170.874	$\frac{3}{4}$	371.543
$\frac{1}{2}$	2.4053	$\frac{7}{8}$	48.7071	$\frac{7}{8}$	173.782	$\frac{7}{8}$	375.826
$\frac{3}{8}$	2.7612	8.....	50.2656	15.....	176.715	22.....	380.134
2.....	3.1416	$\frac{1}{8}$	51.8487	$\frac{1}{8}$	179.673	$\frac{1}{8}$	384.466
$\frac{1}{8}$	3.5466	$\frac{1}{4}$	53.4563	$\frac{1}{4}$	182.655	$\frac{1}{4}$	388.822
$\frac{1}{4}$	3.9761	$\frac{3}{8}$	55.0884	$\frac{3}{8}$	185.661	$\frac{3}{8}$	393.203
$\frac{3}{8}$	4.4301	$\frac{1}{2}$	56.7451	$\frac{1}{2}$	188.692	$\frac{1}{2}$	397.609
$\frac{1}{2}$	4.9087	$\frac{5}{8}$	58.4264	$\frac{5}{8}$	191.748	$\frac{5}{8}$	402.038
$\frac{3}{4}$	5.4119	$\frac{3}{4}$	60.1322	$\frac{3}{4}$	194.828	$\frac{3}{4}$	406.494
$\frac{1}{2}$	5.9396	$\frac{7}{8}$	61.8625	$\frac{7}{8}$	197.933	$\frac{7}{8}$	410.973
$\frac{3}{8}$	6.4918	9.....	63.6174	16.....	201.062	23.....	415.477
3.....	7.0686	$\frac{1}{8}$	65.3968	$\frac{1}{8}$	204.216	$\frac{1}{8}$	420.004
$\frac{1}{8}$	7.6699	$\frac{1}{4}$	67.2008	$\frac{1}{4}$	207.395	$\frac{1}{4}$	424.558
$\frac{1}{4}$	8.2958	$\frac{3}{8}$	69.0293	$\frac{3}{8}$	210.598	$\frac{3}{8}$	429.135
$\frac{3}{8}$	8.9462	$\frac{1}{2}$	70.8823	$\frac{1}{2}$	213.825	$\frac{1}{2}$	433.737
$\frac{1}{2}$	9.6211	$\frac{5}{8}$	72.7599	$\frac{5}{8}$	217.077	$\frac{5}{8}$	438.364
$\frac{3}{4}$	10.3206	$\frac{3}{4}$	74.6621	$\frac{3}{4}$	220.354	$\frac{3}{4}$	443.015
$\frac{1}{2}$	11.0447	$\frac{7}{8}$	76.5888	$\frac{7}{8}$	223.655	$\frac{7}{8}$	447.69
$\frac{3}{8}$	11.7933	10.....	78.54	17.....	226.981	24.....	452.39
4.....	12.5664	$\frac{1}{8}$	80.5158	$\frac{1}{8}$	230.331	$\frac{1}{8}$	457.115
$\frac{1}{8}$	13.3641	$\frac{1}{4}$	82.5161	$\frac{1}{4}$	233.706	$\frac{1}{4}$	461.864
$\frac{1}{4}$	14.1863	$\frac{3}{8}$	84.5409	$\frac{3}{8}$	237.105	$\frac{3}{8}$	466.638
$\frac{3}{8}$	15.033	$\frac{1}{2}$	86.5903	$\frac{1}{2}$	240.529	$\frac{1}{2}$	471.436
$\frac{1}{2}$	15.9043	$\frac{5}{8}$	88.6643	$\frac{5}{8}$	243.977	$\frac{5}{8}$	476.259
$\frac{3}{4}$	16.8002	$\frac{3}{4}$	90.7628	$\frac{3}{4}$	247.45	$\frac{3}{4}$	481.107
$\frac{1}{2}$	17.7206	$\frac{7}{8}$	92.8858	$\frac{7}{8}$	250.948	$\frac{7}{8}$	485.979
$\frac{3}{8}$	18.6655	11.....	95.0334	18.....	254.47	25.....	490.875
		$\frac{1}{8}$	97.2055	$\frac{1}{8}$	258.016	$\frac{1}{8}$	495.796
		$\frac{1}{4}$	99.4022	$\frac{1}{4}$	261.587	$\frac{1}{4}$	500.742
		$\frac{3}{8}$	101.6234	$\frac{3}{8}$	265.183	$\frac{3}{8}$	505.712
		$\frac{1}{2}$	103.8691	$\frac{1}{2}$	268.803	$\frac{1}{2}$	510.706
		$\frac{5}{8}$	106.1394	$\frac{5}{8}$	272.448	$\frac{5}{8}$	515.726
		$\frac{3}{4}$	108.4343	$\frac{3}{4}$	276.117	$\frac{3}{4}$	520.769
		$\frac{7}{8}$	110.7537	$\frac{7}{8}$	279.811	$\frac{7}{8}$	525.838
						26.....	530.93

PROPERTIES OF SATURATED STEAM.—Continued.

Absolute pressure in lbs. per square inch.	Temperature in degrees, Fahrenheit.	Heat units per lb., reckoning from zero.	Heat units per lb. contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.	Absolute pressure in lbs. per square inch.	Temperature in degrees, Fahrenheit.	Heat units per lb., reckoning from zero.	Heat units per lb. contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
1	102.0	1145.0	102.1	.0030	20620	60	292.5	1203.2	294.9	.1457	428.5
2	126.3	1152.5	126.4	.0058	10720	61	293.6	1203.5	296	.1479	422
3	141.6	1157.1	141.9	.0085	7326	62	294.7	1203.8	297.1	.1502	415.6
4	153.1	1160.6	153.4	.0112	5600	63	295.7	1204.1	298.2	.1525	409.4
5	162.3	1163.4	162.7	.0137	4535	64	296.8	1204.5	299.2	.1547	403.5
6	170.1	1165.8	170.6	.0163	3814	65	297.8	1204.8	300.3	.1570	397.7
7	176.9	1167.9	177.4	.0189	3300	66	298.8	1205.1	301.3	.1592	392.1
8	182.9	1169.7	183.5	.0214	2910	67	299.8	1205.4	302.4	.1615	386.6
9	188.3	1171.4	188.9	.0239	2607	68	300.8	1205.7	303.4	.1637	381.3
10	193.2	1172.9	193.9	.0264	2360	69	301.8	1206	304.4	.1660	376.1
11	197.8	1174.2	198.5	.0289	2157	70	302.7	1206.3	305.4	.1682	371.2
12	202	1175.5	202.7	.0313	1988	71	303.7	1206.6	306.4	.1704	366.4
13	205.9	1176.7	206.7	.0337	1846	72	304.6	1206.9	307.3	.1726	361.7
14	209.6	1177.9	210.4	.0362	1722	73	305.6	1207.1	308.3	.1748	357.1
14.7	212	1178.6	212.9	.0380	1644	74	306.5	1207.4	309.3	.1770	352.6
15	213.1	1178.9	213.9	.0387	1612	75	307.4	1207.7	310.2	.1792	348.3
16	216.3	1179.9	217.2	.0413	1514	76	308.3	1208	311.1	.1814	344.1
17	219.4	1180.9	220.4	.0437	1427	77	309.2	1208.2	312	.1836	340
18	222.4	1181.8	223.4	.0462	1351	78	310.1	1208.5	313	.1858	336
19	225.2	1182.6	226.3	.0487	1282.1	79	310.9	1208.8	313.8	.1880	332.1
20	227.9	1183.5	229	.0511	1220.3	80	311.8	1209	314.7	.1901	328.3
21	230.5	1184.2	231.7	.0536	1164.4	81	312.7	1209.3	315.6	.1923	324.6
22	233	1185	234.2	.0561	1113.5	82	313.5	1209.6	316.5	.1945	320.9
23	235.4	1185.7	236.7	.0585	1066.9	83	314.4	1209.8	317.3	.1967	317.3
24	237.7	1186.5	239	.0610	1024.1	84	315.2	1210	318.2	.1989	313.9
25	240.	1187.1	241.3	.0634	984.8	85	316	1210.3	319	.2010	310.5
26	242.2	1187.8	243.5	.0658	948.4	86	316.8	1210.6	319.9	.2032	307.2
27	244.3	1188.5	245.7	.0683	914.6	87	317.6	1210.8	320.7	.2053	304
28	246.3	1189	247.7	.0707	883.2	88	318.5	1211	321.5	.2075	300.8
29	248.3	1189.7	249.8	.0731	854	89	319.3	1211.3	322.4	.2097	297.7
30	250.2	1190.3	251.7	.0755	826.8	90	320	1211.6	323.2	.2118	294.7
31	252.1	1190.8	253.6	.0779	801.2	91	320.8	1211.8	324	.2139	291.8
32	254	1191.4	255.5	.0803	777.2	92	321.6	1212	324.8	.2161	288.9
33	255.7	1191.9	257.3	.0827	754.7	93	322.4	1212.3	325.6	.2183	286.1
34	257.5	1192.5	259.1	.0851	733.5	94	323.1	1212.5	326.4	.2204	283.3
35	259.2	1193	260.8	.0875	713.4	95	323.9	1212.7	327.1	.2225	280.6
36	260.9	1193.5	262.5	.0899	694.5	96	324.6	1213	327.9	.2245	278
37	262.5	1194	264.2	.0922	676.6	97	325.4	1213.2	328.7	.2267	275.4
38	264	1194.5	265.8	.0946	659.7	98	326.1	1213.4	329.4	.2288	272.8
39	265.6	1195	267.4	.0970	643.6	99	326.8	1213.6	330.2	.2309	270.3
40	267.1	1195.4	268.9	.0994	628.2	100	327.6	1213.8	331	.2330	267.9
41	264.6	1195.9	270.5	.1017	613.4	101	328.3	1214	331.7	.2351	265.5
42	270.1	1196.3	272	.1041	599.3	102	329	1214.3	332.4	.2372	263.2
43	271.5	1196.7	273.4	.1064	586.1	103	329.7	1214.5	333.1	.2392	260.9
44	272.9	1197.2	274.9	.1088	573.7	104	330.4	1214.7	333.9	.2413	258.7
45	274.3	1197.6	276.3	.1111	561.8	105	331.1	1214.9	334.6	.2434	256.5
46	275.7	1198	277.7	.1134	550.4	106	331.8	1215.1	335.3	.2455	254.3
47	277	1198.4	279	.1158	539.5	107	332.2	1215.3	336	.2475	252.2
48	278.3	1198.8	280.4	.1181	529	108	332.5	1215.6	336.7	.2496	250.1
49	279.6	1199.2	281.7	.1204	518.6	109	333.2	1215.8	337.4	.2517	248
50	280.9	1199.6	283	.1227	508.5	110	334.5	1216	338.1	.2538	246
51	282.1	1200	284.2	.1251	499.1	111	335.2	1216.2	338.8	.2558	244
52	283.3	1200.4	285.5	.1274	490.1	112	335.9	1216.4	339.5	.2579	242
53	284.5	1200.7	286.7	.1297	481.4	113	336.5	1216.6	340.2	.2599	240.1
54	285.7	1201.1	288	.1320	472.9	114	337.2	1216.8	340.8	.2620	238.2
55	286.9	1201.4	289.2	.1343	464.7	115	337.8	1217	341.5	.2640	236.3
56	288.1	1201.8	290.3	.1366	457	116	338.5	1217.2	342.2	.2661	234.5
57	289.1	1202.1	291.5	.1388	449.6	117	339.1	1217.4	342.8	.2682	232.7
58	290.3	1202.5	292.7	.1411	442.4	118	339.7	1217.6	343.5	.2702	231
59	291.4	1202.8	293.8	.1434	435.3	119	340.4	1217.8	344.2	.2722	229.3

PROPERTIES OF SATURATED STEAM.—Continued.

Absolute pressure in lbs. per square inch.	Temperature in degrees, Fahrenheit.	Heat units per lb., reckoning from zero.	Heat units per lb. contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.	Absolute pressure in lbs. per square inch.	Temperature in degrees, Fahrenheit.	Heat units per lb., reckoning from zero.	Heat units per lb. contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
120	341	1217.9	344.8	.2743	227.6	156	361.2	1224.1	365.8	.3448	181.3
121	341.6	1218.1	345.4	.2763	226	157	361.8	1224.3	366.3	.3467	180.3
122	342.2	1218.3	346.1	.2783	224.4	158	362.3	1224.4	366.8	.3485	179.3
123	342.9	1218.5	346.7	.2803	222.8	159	362.8	1224.6	367.3	.3503	178.3
124	343.5	1218.7	347.3	.2823	221.2	160	363.3	1224.8	367.9	.3521	177.3
125	344.1	1218.9	348	.2843	219.7	161	363.8	1224.9	368.4	.3540	176.4
126	344.7	1219.1	348.6	.2862	219.2	162	364.3	1225	368.9	.3558	175.5
127	345.3	1219.3	349.2	.2882	216.7	163	364.8	1225.2	369.4	.3577	174.6
128	345.9	1219.4	349.8	.2902	215.2	164	365.2	1225.3	369.9	.3596	173.7
129	346.5	1219.6	350.4	.2922	213.7	165	365.7	1225.5	370.4	.3615	172.8
130	347.1	1219.8	351.1	.2942	212.3	166	366.2	1225.6	370.9	.3634	171.9
131	347.6	1220	351.7	.2962	210.9	167	366.7	1225.8	371.4	.3652	171
132	348.2	1220.2	352.3	.2982	209.5	168	367.2	1225.9	371.9	.3671	170.1
133	348.8	1220.4	352.9	.3001	208.1	169	367.7	1226.1	372.4	.3690	169.2
134	349.4	1220.5	353.5	.3021	206.7	170	368.2	1226.2	372.9	.3709	168.4
135	350	1220.7	354.1	.3040	205.4	171	368.6	1226.4	373.4	.3727	167.6
136	350.5	1220.9	354.6	.3060	204.1	172	369.1	1226.5	373.9	.3745	166.8
137	351.1	1221	355.2	.3080	202.8	173	369.6	1226.7	374.4	.3763	166
138	351.7	1221.2	355.8	.3099	201.5	174	370	1226.8	374.9	.3781	165.2
139	352.2	1221.4	356.4	.3119	200.2	175	370.5	1226.9	375.4	.3799	164.4
140	352.8	1221.5	357	.3139	199	176	371	1227.1	375.9	.3817	163.6
141	353.3	1221.7	357.5	.3159	197.8	177	371.4	1227.2	376.3	.3835	162.8
142	353.9	1221.9	358.1	.3179	196.6	178	371.9	1227.4	376.8	.3853	162
143	354.4	1222	358.7	.3199	195.4	179	372.4	1227.5	377.3	.3871	161.2
144	355	1222.2	359.2	.3219	194.2	180	372.8	1227.7	377.8	.3889	160.4
145	355.5	1222.4	359.8	.3239	193	181	373.3	1227.8	378.3	.3908	159.7
146	356	1222.5	360.4	.3259	191.9	182	373.7	1227.9	378.7	.3926	159
147	356.6	1222.7	360.9	.3279	190.8	183	374.2	1228.1	379.2	.3944	158.3
148	357.1	1222.9	361.5	.3299	189.7	184	374.6	1228.2	379.7	.3962	157.6
149	357.6	1223	362	.3326	188.6	185	375.1	1228.3	380.1	.3981	156.9
150	358.1	1223.2	362.6	.3340	187.5	186	375.5	1228.5	380.6	.3999	156.2
151	358.7	1223.3	363.1	.3358	186.4	187	376	1228.6	381.1	.4017	155.5
152	359.2	1223.5	363.6	.3376	185.3	188	376.4	1228.7	381.5	.4036	154.8
153	359.7	1223.7	364.2	.3394	184.3	189	376.9	1228.9	382	.4054	154.1
154	360.2	1223.9	364.7	.3412	183.3	190	377.3	1229	382.4	.4072	154.4
155	360.7	1224	365.2	.3430	182.3						

Rule for Steam Heating.

Allow one square foot heating surface in a boiler for every 200 cubic feet of space in a church or hall. In a dwelling-house every 50 cubic feet of space requires one square foot of boiler heating surface. The radiators should have one square foot of superficial to every six square feet of glass in windows, and one square foot for every 80 cubic feet of space to be heated. One horse power in a boiler is generally sufficient for 40,000 cubic feet of space for a temperature of 70° Fahr.

Miscellaneous.

For the	Area of a Circle	× sq. of Dia. by	.7854
"	Dia. " "	× cir. by	.31831
"	Cir. " "	× Dia. by	3.1416
"	Surface of a Ball	× sq. of Dia. by	3.1416
"	Cu. in. in a "	× cube of Dia. by	.5236
"	Side of an Equal Sq.	× Dia. by	.8862

In calculating horse powers of steam boilers, consider for :

Tubular boilers 15 sq. ft. of heating surface equivalent to one horse power.

Flue boilers 12 sq. ft. of heating surface equivalent to one horse power.

According to experiments conducted by Mr. Sherwood, U. S. N., the best proportion for the draft of a chimney is $\frac{1}{3}$ of the area of grate surface.

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam. Ins.	Circum. Ins.	Area. Sq. ins.	Diam. Ins.	Circum. Ins.	Area. Sq. ins.	Diam. Ins.	Circum. Ins.	Area. Sq. ins.
1	1.0635	.00907	10	31.416	78.540	20	62.832	314.160
1 $\frac{1}{2}$	3.027	.0122	11	34.557	95.033	21	65.973	346.361
2	7.854	.0490	12	37.699	113.097	22	69.115	380.133
2 $\frac{1}{2}$	11.781	.1104	13	40.840	132.732	23	72.256	415.476
3	15.708	.1903	14	43.982	153.938	24	75.398	452.390
3 $\frac{1}{2}$	19.635	.3068	15	47.124	176.715	25	78.540	490.875
4	23.562	.4417	16	50.265	201.062	26	81.681	530.930
4 $\frac{1}{2}$	27.489	.6013	17	53.407	226.980	27	84.823	572.556
5	31.416	.7854	18	56.548	254.469	28	87.964	615.753
5 $\frac{1}{2}$	35.343	.9940	19	59.690	283.529	29	91.106	660.521
6	39.270	1.2271	20	62.832	314.160	30	94.247	707.714
6 $\frac{1}{2}$	43.197	1.4848	21	65.973	346.361	31	97.389	757.377
7	47.124	1.7671	22	69.115	380.133	32	100.530	809.589
7 $\frac{1}{2}$	51.051	2.0739	23	72.256	415.476	33	103.671	864.363
8	54.978	2.4052	24	75.398	452.390	34	106.812	921.728
8 $\frac{1}{2}$	58.905	2.7611	25	78.540	490.875	35	109.953	981.703
9	62.832	3.1416	26	81.681	530.930	36	113.094	1044.318
9 $\frac{1}{2}$	66.759	3.5465	27	84.823	572.556	37	116.235	1109.593
10	70.686	3.9760	28	87.964	615.753	38	119.376	1177.548
10 $\frac{1}{2}$	74.613	4.4302	29	91.106	660.521	39	122.517	1248.203
11	78.540	4.9087	30	94.247	707.714	40	125.658	1321.568
11 $\frac{1}{2}$	82.467	5.4119	31	97.389	757.377	41	128.799	1397.663
12	86.394	5.9395	32	100.530	809.589	42	131.940	1476.508
12 $\frac{1}{2}$	90.321	6.4918	33	103.671	864.363	43	135.081	1558.123
13	94.248	7.0686	34	106.812	921.728	44	138.222	1642.528
13 $\frac{1}{2}$	98.175	7.6699	35	109.953	981.703	45	141.363	1729.743
14	102.102	8.2957	36	113.094	1044.318	46	144.504	1819.768
14 $\frac{1}{2}$	106.029	8.9462	37	116.235	1109.593	47	147.645	1912.613
15	109.956	9.6211	38	119.376	1177.548	48	150.786	2008.298
15 $\frac{1}{2}$	113.883	10.320	39	122.517	1248.203	49	153.927	2106.833
16	117.810	11.044	40	125.658	1321.568	50	157.068	2208.128
16 $\frac{1}{2}$	121.737	11.793	41	128.799	1397.663	51	160.209	2312.183
17	125.664	12.566	42	131.940	1476.508	52	163.350	2418.998
17 $\frac{1}{2}$	129.591	13.363	43	135.081	1558.123	53	166.491	2528.573
18	133.518	14.186	44	138.222	1642.528	54	169.632	2640.918
18 $\frac{1}{2}$	137.445	15.033	45	141.363	1729.743	55	172.773	2756.043
19	141.372	15.904	46	144.504	1819.768	56	175.914	2873.968
19 $\frac{1}{2}$	145.300	16.800	47	147.645	1912.613	57	179.055	2994.703
20	149.227	17.720	48	150.786	2008.298	58	182.196	3118.248
20 $\frac{1}{2}$	153.154	18.665	49	153.927	2106.833	59	185.337	3244.603
21	157.081	19.635	50	157.068	2208.128	60	188.478	3373.778
21 $\frac{1}{2}$	161.008	20.629	51	160.209	2312.183	61	191.619	3505.783
22	164.935	21.647	52	163.350	2418.998	62	194.760	3640.628
22 $\frac{1}{2}$	168.862	22.690	53	166.491	2528.573	63	197.901	3779.323
23	172.789	23.758	54	169.632	2640.918	64	201.042	3921.878
23 $\frac{1}{2}$	176.716	24.850	55	172.773	2756.043	65	204.183	4068.293
24	180.643	25.967	56	175.914	2873.968	66	207.324	4218.568
24 $\frac{1}{2}$	184.570	27.108	57	179.055	2994.703	67	210.465	4372.713
25	188.497	28.274	58	182.196	3118.248	68	213.606	4530.728
25 $\frac{1}{2}$	192.424	29.464	59	185.337	3244.603	69	216.747	4692.613
26	196.351	30.679	60	188.478	3373.778	70	219.888	4858.368
26 $\frac{1}{2}$	200.278	31.919	61	191.619	3505.783	71	223.029	5028.003
27	204.205	33.183	62	194.760	3640.628	72	226.170	5201.518
27 $\frac{1}{2}$	208.132	34.471	63	197.901	3779.323	73	229.311	5378.913
28	212.059	35.784	64	201.042	3921.878	74	232.452	5560.188
28 $\frac{1}{2}$	215.986	37.122	65	204.183	4068.293	75	235.593	5745.343
29	219.913	38.484	66	207.324	4218.568	76	238.734	5934.398
29 $\frac{1}{2}$	223.840	39.871	67	210.465	4372.713	77	241.875	6127.353
30	227.767	41.282	68	213.606	4530.728	78	245.016	6324.208
30 $\frac{1}{2}$	231.694	42.718	69	216.747	4692.613	79	248.157	6525.063
31	235.621	44.178	70	219.888	4858.368	80	251.298	6730.918
31 $\frac{1}{2}$	239.548	45.663	71	223.029	5028.003	81	254.439	6941.773
32	243.475	47.173	72	226.170	5201.518	82	257.580	7156.628
32 $\frac{1}{2}$	247.402	48.707	73	229.311	5378.913	83	260.721	7375.483
33	251.329	50.265	74	232.452	5560.188	84	263.862	7598.338
33 $\frac{1}{2}$	255.256	51.848	75	235.593	5745.343	85	267.003	7825.193
34	259.183	53.456	76	238.734	5934.398	86	270.144	8056.048
34 $\frac{1}{2}$	263.110	55.088	77	241.875	6127.353	87	273.285	8290.903
35	267.037	56.743	78	245.016	6324.208	88	276.426	8530.758
35 $\frac{1}{2}$	270.964	58.420	79	248.157	6525.063	89	279.567	8774.613
36	274.891	60.122	80	251.298	6730.918	90	282.708	9022.468
36 $\frac{1}{2}$	278.818	61.862	81	254.439	6941.773	91	285.849	9274.323
37	282.745	63.617	82	257.580	7156.628	92	288.990	9530.178
37 $\frac{1}{2}$	286.672	65.396	83	260.721	7375.483	93	292.131	9790.033
38	290.600	67.200	84	263.862	7598.338	94	295.272	10054.888
38 $\frac{1}{2}$	294.527	69.029	85	267.003	7825.193	95	298.413	10323.743
39	298.454	70.882	86	270.144	8056.048	96	301.554	10596.598
39 $\frac{1}{2}$	302.381	72.750	87	273.285	8290.903	97	304.695	10873.453
40	306.308	74.662	88	276.426	8530.758	98	307.836	11154.308
40 $\frac{1}{2}$	310.235	76.588	89	279.567	8774.613	99	310.977	11439.163
41	314.162	78.540	90	282.708	9022.468	100	314.118	11728.018

CIRCUMFERENCES AND AREAS OF CIRCLES—continued.

Diam. Ins.	Circum. Ins.	Area. Sq. ins.
30	94.248	706.860
$\frac{1}{16}$	94.640	712.762
$\frac{1}{8}$	95.033	718.690
$\frac{3}{16}$	95.426	724.641
$\frac{1}{2}$	95.818	730.618
$\frac{5}{8}$	96.211	736.619
$\frac{3}{4}$	96.604	742.644
$\frac{7}{8}$	96.996	748.694
31	97.389	754.769
$\frac{1}{16}$	97.782	760.868
$\frac{1}{8}$	98.175	766.992
$\frac{3}{16}$	98.567	773.140
$\frac{1}{2}$	98.968	779.313
$\frac{5}{8}$	99.353	785.510
$\frac{3}{4}$	99.745	791.732
$\frac{7}{8}$	100.138	797.978
32	100.531	804.249
$\frac{1}{16}$	100.924	810.545
$\frac{1}{8}$	101.316	816.865
$\frac{3}{16}$	101.709	823.209
$\frac{1}{2}$	102.102	829.578
$\frac{5}{8}$	102.494	835.972
$\frac{3}{4}$	102.887	842.390
$\frac{7}{8}$	103.280	848.833
33	103.672	855.30
$\frac{1}{16}$	104.055	861.79
$\frac{1}{8}$	104.458	868.30
$\frac{3}{16}$	104.850	874.84
$\frac{1}{2}$	105.243	881.41
$\frac{5}{8}$	105.636	888.00
$\frac{3}{4}$	106.029	894.61
$\frac{7}{8}$	106.421	901.25
34	106.814	907.92
$\frac{1}{16}$	107.207	914.61
$\frac{1}{8}$	107.599	921.32
$\frac{3}{16}$	107.992	928.06
$\frac{1}{2}$	108.385	934.82
$\frac{5}{8}$	108.777	941.60
$\frac{3}{4}$	109.170	948.41
$\frac{7}{8}$	109.563	955.25
35	109.956	962.11
$\frac{1}{16}$	110.348	968.99
$\frac{1}{8}$	110.741	975.90
$\frac{3}{16}$	111.134	982.84
$\frac{1}{2}$	111.526	989.80
$\frac{5}{8}$	111.919	996.78
$\frac{3}{4}$	112.312	1003.78
$\frac{7}{8}$	112.704	1010.82
36	113.097	1017.87
$\frac{1}{16}$	113.490	1024.95
$\frac{1}{8}$	113.883	1032.06
$\frac{3}{16}$	114.275	1039.19
$\frac{1}{2}$	114.668	1046.35
$\frac{5}{8}$	115.061	1053.52
$\frac{3}{4}$	115.453	1060.73
$\frac{7}{8}$	115.846	1067.95
37	116.239	1075.21
$\frac{1}{16}$	116.631	1082.48
$\frac{1}{8}$	117.024	1089.79
$\frac{3}{16}$	117.417	1097.11
$\frac{1}{2}$	117.810	1104.46
$\frac{5}{8}$	118.202	1111.84
$\frac{3}{4}$	118.595	1119.24
$\frac{7}{8}$	118.988	1126.66
38	119.380	1134.11
$\frac{1}{16}$	119.773	1141.59
$\frac{1}{8}$	120.166	1149.08
$\frac{3}{16}$	120.558	1156.61
$\frac{1}{2}$	120.951	1164.15
$\frac{5}{8}$	121.344	1171.73
$\frac{3}{4}$	121.737	1179.33
$\frac{7}{8}$	122.129	1186.94
39	122.522	1194.59
$\frac{1}{16}$	122.915	1202.26
$\frac{1}{8}$	123.307	1209.95
$\frac{3}{16}$	123.700	1217.67
$\frac{1}{2}$	124.093	1225.42
$\frac{5}{8}$	124.485	1233.18
$\frac{3}{4}$	124.878	1240.98
$\frac{7}{8}$	125.271	1248.79

Diam. Ins.	Circum. Ins.	Area. Sq. ins.
40	125.664	1256.64
$\frac{1}{16}$	126.056	1264.50
$\frac{1}{8}$	126.449	1272.39
$\frac{3}{16}$	126.842	1280.31
$\frac{1}{2}$	127.234	1288.25
$\frac{5}{8}$	127.627	1296.21
$\frac{3}{4}$	128.020	1304.20
$\frac{7}{8}$	128.412	1312.21
41	128.805	1320.25
$\frac{1}{16}$	129.198	1328.32
$\frac{1}{8}$	129.591	1336.40
$\frac{3}{16}$	129.983	1344.51
$\frac{1}{2}$	130.376	1352.65
$\frac{5}{8}$	130.769	1360.81
$\frac{3}{4}$	131.161	1369.00
$\frac{7}{8}$	131.554	1377.21
42	131.947	1385.44
$\frac{1}{16}$	132.339	1393.70
$\frac{1}{8}$	132.732	1401.98
$\frac{3}{16}$	133.125	1410.29
$\frac{1}{2}$	133.518	1418.62
$\frac{5}{8}$	133.910	1426.98
$\frac{3}{4}$	134.303	1435.36
$\frac{7}{8}$	134.696	1443.77
43	135.088	1452.20
$\frac{1}{16}$	135.481	1460.65
$\frac{1}{8}$	135.874	1469.13
$\frac{3}{16}$	136.266	1477.63
$\frac{1}{2}$	136.659	1486.17
$\frac{5}{8}$	137.052	1494.72
$\frac{3}{4}$	137.445	1503.30
$\frac{7}{8}$	137.837	1511.90
44	138.230	1520.53
$\frac{1}{16}$	138.623	1529.18
$\frac{1}{8}$	139.015	1537.86
$\frac{3}{16}$	139.408	1546.55
$\frac{1}{2}$	139.801	1555.28
$\frac{5}{8}$	140.193	1564.03
$\frac{3}{4}$	140.586	1572.81
$\frac{7}{8}$	140.979	1581.61
45	141.372	1590.43
$\frac{1}{16}$	141.764	1599.28
$\frac{1}{8}$	142.157	1608.15
$\frac{3}{16}$	142.550	1617.04
$\frac{1}{2}$	142.942	1625.97
$\frac{5}{8}$	143.335	1634.92
$\frac{3}{4}$	143.728	1643.89
$\frac{7}{8}$	144.120	1652.88
46	144.513	1661.90
$\frac{1}{16}$	144.906	1670.95
$\frac{1}{8}$	145.299	1680.01
$\frac{3}{16}$	145.691	1689.10
$\frac{1}{2}$	146.084	1698.23
$\frac{5}{8}$	146.477	1707.37
$\frac{3}{4}$	146.869	1716.54
$\frac{7}{8}$	147.262	1725.73
47	147.655	1734.94
$\frac{1}{16}$	148.047	1744.18
$\frac{1}{8}$	148.440	1753.45
$\frac{3}{16}$	148.833	1762.73
$\frac{1}{2}$	149.226	1772.05
$\frac{5}{8}$	149.618	1781.39
$\frac{3}{4}$	150.011	1790.76
$\frac{7}{8}$	150.404	1800.14
48	150.796	1809.56
$\frac{1}{16}$	151.189	1818.99
$\frac{1}{8}$	151.582	1828.46
$\frac{3}{16}$	151.974	1837.93
$\frac{1}{2}$	152.367	1847.45
$\frac{5}{8}$	152.760	1856.99
$\frac{3}{4}$	153.153	1866.55
$\frac{7}{8}$	153.545	1876.13
49	153.938	1885.74
$\frac{1}{16}$	154.331	1895.37
$\frac{1}{8}$	154.723	1905.03
$\frac{3}{16}$	155.116	1914.70
$\frac{1}{2}$	155.509	1924.42
$\frac{5}{8}$	155.901	1934.15
$\frac{3}{4}$	156.294	1943.91
$\frac{7}{8}$	156.687	1953.69

Diam. Ins.	Circum. Ins.	Area. Ins.
50	157.080	1963.50
$\frac{1}{16}$	157.865	1983.18
$\frac{1}{8}$	158.650	2002.96
$\frac{3}{16}$	159.436	2022.84
51	160.221	2042.82
$\frac{1}{16}$	161.007	2062.90
$\frac{1}{8}$	161.792	2083.07
$\frac{3}{16}$	162.577	2103.35
52	163.363	2123.72
$\frac{1}{16}$	164.148	2144.19
$\frac{1}{8}$	164.934	2164.75
$\frac{3}{16}$	165.719	2185.42
53	166.504	2206.18
$\frac{1}{16}$	167.290	2227.05
$\frac{1}{8}$	168.075	2248.01
$\frac{3}{16}$	168.861	2269.06
54	169.646	2290.22
$\frac{1}{16}$	170.431	2311.48
$\frac{1}{8}$	171.217	2332.83
$\frac{3}{16}$	172.002	2354.28
55	172.788	2375.83
$\frac{1}{16}$	173.573	2397.48
$\frac{1}{8}$	174.358	2419.22
$\frac{3}{16}$	175.144	2441.07
56	175.929	2463.01
$\frac{1}{16}$	176.715	2485.05
$\frac{1}{8}$	177.500	2507.19
$\frac{3}{16}$	178.285	2529.42
57	179.071	2551.76
$\frac{1}{16}$	179.856	2574.19
$\frac{1}{8}$	180.642	2596.72
$\frac{3}{16}$	181.427	2619.35
58	182.212	2642.08
$\frac{1}{16}$	182.998	2664.91
$\frac{1}{8}$	183.783	2687.83
$\frac{3}{16}$	184.569	2710.85
59	185.354	2733.97
$\frac{1}{16}$	186.139	2757.19
$\frac{1}{8}$	186.925	2780.51
$\frac{3}{16}$	187.710	2803.92
60	188.496	2827.44
$\frac{1}{16}$	189.281	2851.05
$\frac{1}{8}$	190.066	2874.76
$\frac{3}{16}$	190.852	2898.56
61	191.637	2922.47
$\frac{1}{16}$	192.423	2946.47
$\frac{1}{8}$	193.208	2970.57
$\frac{3}{16}$	193.993	2994.77
62	194.779	3019.07
$\frac{1}{16}$	195.564	3043.47
$\frac{1}{8}$	196.350	3067.96
$\frac{3}{16}$	197.135	3092.56
63	197.920	3117.25
$\frac{1}{16}$	198.706	3142.04
$\frac{1}{8}$	199.491	3166.92
$\frac{3}{16}$	200.277	3191.91
64	201.062	3216.99
$\frac{1}{16}$	201.847	3242.17
$\frac{1}{8}$	202.683	3267.46
$\frac{3}{16}$	203.418	3292.83
65	204.204	3318.31
$\frac{1}{16}$	204.989	3343.88
$\frac{1}{8}$	205.774	3369.56
$\frac{3}{16}$	206.560	3395.33
66	207.345	3421.20
$\frac{1}{16}$	208.131	3447.16
$\frac{1}{8}$	208.916	3473.23
$\frac{3}{16}$	209.701	3499.39
67	210.487	3525.66
$\frac{1}{16}$	211.272	3552.01
$\frac{1}{8}$	212.058	3578.47
$\frac{3}{16}$	212.843	3605.03

CIRCUMFERENCES AND AREAS OF CIRCLES—continued.

Diam. Ins.	Circum. Ins.	Area. Sq. ins.	Diam. Ins.	Circum. Ins.	Area. Sq. ins.	Diam. Ins.	Circum. Ins.	Area. Sq. ins.
68	213.628	3631.68	76	238.761	4536.37	87	273.319	5944.06
$\frac{1}{4}$	214.414	3658.44	$\frac{1}{4}$	239.547	4566.36	$\frac{1}{2}$	274.890	6013.21
$\frac{1}{2}$	215.190	3685.20	$\frac{1}{2}$	240.332	4596.35			
$\frac{3}{4}$	215.985	3712.24	$\frac{3}{4}$	241.117	4626.44	88	276.460	6082.13
						$\frac{1}{2}$	278.031	6151.44
69	216.770	3739.28	77	241.903	4656.63			
$\frac{1}{4}$	217.555	3766.43	$\frac{1}{4}$	242.688	4686.92	89	279.602	6221.15
$\frac{1}{2}$	218.341	3793.67	$\frac{1}{2}$	243.474	4717.30	$\frac{1}{2}$	281.173	6291.25
$\frac{3}{4}$	219.126	3821.02	$\frac{3}{4}$	244.259	4747.70			
						90	282.744	6361.74
70	219.912	3848.46	78	245.044	4778.37	$\frac{1}{2}$	284.314	6432.62
$\frac{1}{4}$	220.697	3875.99	$\frac{1}{4}$	245.830	4809.05			
$\frac{1}{2}$	221.482	3903.63	$\frac{1}{2}$	246.615	4839.83	91	285.885	6503.89
$\frac{3}{4}$	222.268	3931.36	$\frac{3}{4}$	247.401	4870.70	$\frac{1}{2}$	287.456	6573.56
71	223.053	3959.20	79	248.186	4901.68	92	289.027	6647.62
$\frac{1}{4}$	223.839	3987.13	$\frac{1}{4}$	248.971	4932.75	$\frac{1}{2}$	290.598	6720.07
$\frac{1}{2}$	224.624	4015.16	$\frac{1}{2}$	249.757	4963.92			
$\frac{3}{4}$	225.409	4043.28	$\frac{3}{4}$	250.542	4995.19	93	292.168	6792.92
						$\frac{1}{2}$	293.739	6866.16
72	226.195	4071.51	80	251.328	5026.56			
$\frac{1}{4}$	226.980	4099.83	$\frac{1}{2}$	252.898	5089.58	94	295.310	6939.79
$\frac{1}{2}$	227.766	4128.25				$\frac{1}{2}$	296.881	7013.81
$\frac{3}{4}$	228.551	4156.77	81	254.469	5153.00			
			$\frac{1}{2}$	256.040	5216.82	95	298.452	7088.23
73	229.336	4185.39				$\frac{1}{2}$	300.022	7163.04
$\frac{1}{4}$	230.122	4214.11	82	257.611	5281.02			
$\frac{1}{2}$	230.907	4242.92	$\frac{1}{2}$	259.182	5345.62	96	301.594	7238.25
$\frac{3}{4}$	231.693	4271.83				97	304.735	7389.83
			83	260.752	5410.62	98	307.877	7542.98
74	232.478	4300.85	$\frac{1}{2}$	262.323	5476.00	99	311.018	7784.10
$\frac{1}{4}$	233.263	4329.95				100	314.159	7854.00
$\frac{1}{2}$	234.049	4359.16	84	263.894	5541.78	101	317.301	8011.86
$\frac{3}{4}$	234.834	4388.47	$\frac{1}{2}$	265.465	5607.95	102	320.442	8171.30
						103	323.584	8332.31
75	235.620	4417.87	85	267.036	5674.51	104	326.725	8494.88
$\frac{1}{4}$	236.405	4447.37	$\frac{1}{2}$	268.606	5741.47	105	329.867	8659.03
$\frac{1}{2}$	237.190	4476.97				106	333.009	8824.75
$\frac{3}{4}$	237.976	4506.67	86	270.177	5808.81	107	336.150	8992.04
			$\frac{1}{2}$	271.748	5876.55	108	339.292	9160.90
						109	342.433	9331.34
						110	345.575	9503.34

To Drill Holes in Glass.

A common steel drill is the best tool to drill holes in glass. The steel should be forged at a low temperature so as to be sure not to burn it, then tempered hard as possible in a bath of salt water that has been well boiled. Such a drill will go through glass very rapidly if kept well moistened with turpentine in which camphor has been dissolved.

To Find the Number of Bricks Required In a Building.

Rule—Multiply the number of cubic feet by 22 $\frac{1}{2}$. The number of cubic feet is found by multiplying the length, height and thickness (in feet) together. Bricks are usually made 8 inches long, 4 inches wide and 2 inches thick; hence it requires 27 bricks to make a cubic foot without mortar, but it is generally assumed that the mortar fills one-sixth of the space.

Solders.

Fine solder is an alloy of two parts of block tin and one part of lead. This is used for fine work, such as soldering the drums of meters, for pewter, etc.

Brazing Solder.

HARD.—One part copper, one part zinc.

SOFT.—Four parts copper, three parts zinc, one part block tin.

Fluxes for Soldering.

Iron or steel.—Borax ten parts and sal ammoniac one part.

Tinned iron.—Resin or chloride of zinc.

Copper and brass.—Sal ammoniac or chloride of zinc.

Lead.—Resin or tallow.

Lead and composition pipes.—Resin and sweet oil.

Zinc.—Chloride of zinc.

Effect of Heat upon Various Bodies.

Wedgewood's zero is 1077° of Fahrenheit, and each degree=130°.

In the designation of the degrees of temperature, the symbol + is omitted when the temperature is above 0; but when it is below the symbol — is prefixed.

	Deg.		Deg.
Acetification ends	88	Lead melts	540
Acetious fermentation begins	78	Mercury boils	662
Air furnace	3300	“ volatilizes	680
Ambergris melts	145	“ freezes	—39
Ammonia boils	140	Milk freezes	—30
Ammonia (liquid) freezes	—46	Naphtha boils	186
Antimony melts	951	Nitric acid spe. gravity 1.424 freezes	—45
Arsenic melts	365	Nitrous oxide freezes	—150
Beeswax melts	151	Olive oil freezes	—36
Bismuth melts	476	Petroleum boils	306
Blood (human) heat	98	Phosphorus melts	108
“ “ freezes	25	“ “ boils	560
Brandy freezes	—7	Pitch melts	91
Brass melts	1900	Platinum melts	3080
Cadmium melts	600	Potassium melts	135
Charcoal burns	800	Proof spirit freezes	—7
Coal tar boils	325	Saltpetre melts	610
Cold, greatest artificial	—166	Sea water freezes	—28
“ “ natural	—56	Silver (fine) melts	1250
Common fire	790	Snow and salt, equal parts	0
Copper melts	2548	Spermacetti melts	112
Glass melts	2377	Spirits of turpentine freezes	14
Gold (fine) melts	2590	Steel melts	2500
Gutta percha softens	145	“ polished, blue	580
Heat, cherry red	1500	“ “ straw color	460
“ “ (Daniell)	1141	Strong wines freeze	—20
“ bright red	1860	Sulphur melts	226
“ red visible by day	1077	Sulphur acid sp. gravity 1.641 freezes	—45
“ white	2900	Sulphur ether freezes	—46
Highest natural temperature, Egypt	117	“ “ boils	98
Ice melts	32	Tallow melts	97
Iron (cast) melts	2100	Tin melts	421
“ (wrought)	2980	Vinegar freezes	—28
“ bright red in the dark	752	Vinous fermentation	60 to 77
“ red hot in twilight	884	Water, in vacuo boils	98
Lard melts	94	Zinc melts	740

Boiling Point.

Water	212°	Sweet oil	412°	Sulphur	570°
Ether	96 to 104°	Alcohol	173°	Turpentine	304°

How to Calculate Speed.

To find the size of a pulley for a main shaft, if the speed of shafts and diameter of pulley on the countershafts are given: Multiply the diameter in inches of pulley by speed of the countershafts and divide by the revolutions of the main shaft, the quotient will be the diameter of the pulley.

EXAMPLE:—What will be the diameter of a pulley on a main shaft making 180 revolutions per minute to drive a 12 inch pulley 450 revolutions per minute? $45 \div 0 \times 12 \div 180 = 30$ inch pulley.

To find the size of a pulley required, if the number of revolutions and size of pulley on the main shaft are given: Multiply the diameter in inches of driving pulley by the revolutions of the main shaft and divide by the speed required; the quotient will be the diameter in inches of the pulley.

EXAMPLE:—What will be the diameter of a pulley to make a countershaft turn 450 revolutions per minute, driven by a 30 inch pulley 180 revolutions per minute? $180 \times 30 \div 450 = 12$ inch pulley.

To find the speed of a countershaft, if the revolutions of the main shaft and size of pulleys are given: Multiply the revolutions of the main shaft by the diameter in inches of the pulley, and divide by the diameter in inches of the pulley on the countershaft; the quotient will be the number of revolutions.

EXAMPLE:—What will be the speed of a countershaft, with a 12 inch pulley driven by a 30 inch pulley 180 revolutions per minute? $180 \times 30 \div 12 = 450$.

Horse Power for Belting.

A simple rule for ascertaining transmitting power of belting without computing speed per minute it travels is to: Multiply diameter of pulley in inches by the number of its revolutions per minute, and this product by width of belt in inches; divide the product by 3,300 for single belting or 2,100 for double belting and the quotient will be the horse power which it will safely transmit.

Table for single leather, four ply rubber and four ply cotton belting. Belts not overloaded.

Speed in Feet per Minute.	WIDTH OF BELT IN INCHES.												
	2 H. P.	3 H. P.	4 H. P.	5 H. P.	6 H. P.	8 H. P.	10 H. P.	12 H. P.	14 H. P.	16 H. P.	18 H. P.	20 H. P.	
400	1	1½	2	2½	3	4	5	6	7	8	9	10	To find the speed in feet per minute multiply the circumference of pulley, in feet, by the number of revolutions.
600	1½	2½	3	3¾	4½	6	7½	9	10½	12	13½	15	
800	2½	3	4	5	6	8	10	12	14	16	18	20	
1,000	2	3¾	5	6½	7½	10	12½	15	17½	20	22½	25	
1,200	3	4½	6	7½	9	12	15	18	21	24	27	30	
1,500	3¾	5½	7½	9½	11½	15	18½	22½	26½	30	33½	37½	
1,800	4½	6½	9	11½	13½	18	22½	27	31½	36	40½	45	
2,000	5	7½	10	12½	15	20	25	30	35	40	45	50	
2,400	6	9	12	15	18	24	30	36	42	48	54	60	
2,800	7	10½	14	17½	21	28	35	42	49	56	63	70	
3,000	7½	11½	15	18½	22½	30	37½	45	52½	60	67½	75	
3,500	8½	13	17½	22	26	35	44	52½	61	70	79	88	
4,000	10	15	20	25	30	40	50	60	70	80	90	100	
4,500	11½	17	22½	28	34	45	57	69	78	90	102	114	
5,000	12½	19	25	31	37½	50	62½	75	87½	100	112	125	

For Calculating Speed of Pulleys.

To find the number of revolutions of the driven pulley.

Multiply the diameter of the driver by its revolutions and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

2. To find the diameter of the driven that shall make any given number of revolutions in the same time as the driver. Multiply the driver by its revolutions and divide the product by the number of revolutions desired; the quotient will be the diameter for the driven.

3. To find the size for a driver: Multiply the size of the driven by the number of revolutions you wish to make and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

These rules are practically correct, though owing to the slip and thickness of the belt the driven seldom makes exactly the number of revolutions it should.

To Find Length of Belt.

When it is not convenient to measure with the tape line the length required, the following rule will be of service: Add the diameters of the two pulleys together, divide the result by 2, and multiply the quotient by 3½; add the product to twice the distance between the centres of the shafts and you have the length required, substantially.

LEVERS

Are those simple machines that enter into the construction of all other machines of magnitude. The weight signifies the body of the resistance to be overcome, and the power is the force employed to overcome the resistance. They are generally expressed by the first letters in their names: first, W—F—P; second, F—W—P; third, F—P—W; in the first and second kinds there is a gain of power but a loss of speed; in the third kind there is a loss of power but a gain in velocity. As no instrument can be made by man to save both time and force, the maxim is, what we gain in the one is at the expense of the other.

Formula 1 $\frac{\text{Weight} \times \text{Dist. from Fulc.}}{\text{Dist. of Power from Fulc.}} = \text{power}$; Formula 2 $\frac{\text{Power} \times \text{Dist. from Fulc.}}{\text{Dist. of Weight from Fulc.}} = \text{Weight}$.

Formula 3 $\frac{\text{Weight} \times \text{Dist. from Fulc.}}{\text{Power}} = \text{Dist. of Power from Fulc.}$ Formula 4 $\frac{\text{Power} \times \text{Dist. from Fulc.}}{\text{Weight}} = \text{Dist. of Weight from Fulc.}$

Suppose a lever of the first kind having three weights 7, 8, and 9 lbs. at the distance of 6, 15 and 29 inches from fulc. on the one side, and a power of 17 lbs. at the distance of 9 inches on the other side of fulc. Then a weight is to be applied at the distance of 12 inches on the last mentioned side, what must the weight be to balance the lever? Example— $6 \times 7 + 15 \times 8 + 29 \times 9 = 423$ lbs. Then on the other side of fulc. $17 \times 9 = 153$, a difference of 270, this ÷ by 12 inches = 22½ lbs., and $270 + 153 = 423$ lbs. the balance.

When two or more levers act upon each other in succession then the entire advantage which they give is found by adding together the product of their separate advantages.

A lever of the third kind. Suppose the area of a valve is one square inch. From stem to fulcrum is two inches, and a weight of 10 lbs. is placed at 18 inches from fulcrum, what

weight is on the valve $\frac{10 \times 18}{2} = 90$ lbs.? Now if we mark this theoretical lever successively at every two inches, we will have at 2 inches, 10 lbs.; at 4 inches, 20 lbs.; at 6 inches, 30 lbs., etc. In this case we have not considered the weight of the valve and stem nor the effect of the lever on the valve.

Suppose we want to find the weight to hang on a lever 36 inches from fulc., the lever is uniform in dimensions and it is to be graduated to carry from 20 to 80 lbs. per square inch. From fulcrum to valve is 3 inches, diameter of valve is 4 inches, weight of valve and stem $4\frac{1}{2}$ lbs., weight of lever $10\frac{1}{2}$ lbs. $\frac{F3 \times -18 \times 18 - 36}{4 \times 1-2 \times 10 \times 1-2} \parallel$ Ex. $4^2 \times .7854 = 12.5664 \times 80 = 1005.3120$, subtract from this the effective weight of the lever and weight of the valve and stem. The centre of gravity of the lever will be 18 inches $\div$ by 3 inches = 6 inches $\times 10\frac{1}{2}$ = 63.0 lbs., to which add the weight of valve and stem $4.5 = 67.5$ lbs.—this subtracted from $1005.3120 = 937.812 \div 12 = 78.151$ lbs. the weight 78 lbs. $2\frac{1}{2}$ oz. nearly.

NOTE.—Dividing by the ratio 12 is the same as $\times$ by 3 and $\div$ 36.

SECOND.—To find the point on the lever whereon to hang the weight of 78.151 lbs. to balance 20 lbs. internal pressure. When $4^2 \times .7854 = 12.5664 \times 20$ lbs. per sq. inch = 251.3280; subtract the constant 67.5, as in the previous example = 183.828 $\times 3$ inches (short arm) = 551.484 $\div 78.151 = 7.05664$ inches ($7\frac{3}{4}$) from fulc., to hang the weight to balance 20 lbs. per square inch. Now, the difference between the length on lever for 20 lbs. and that for 80 lbs. is 28.9434 inches; divide this by 60 lbs. because 60 is the difference between 20 and 80 lbs., the quotient is .48239 inches ($\frac{3}{8}$). This distance graduates the lever for every lb. Multiply .48239 by 10 = 4.8239 ($4\frac{1}{8}$) marks the lever for every 10 lbs., less the coefficient of friction—the only force in nature entirely inert; its tendency is to destroy motion, and may be viewed as an obstruction to human progress; but, like all the other forces in nature, if it is a hindrance on one hand it is a benefit on the other, as it is the chief cause of structural stability and permanence to moving forces.

THIRD.—The same data to find the area and diameter of valve. Example:

$$\begin{array}{r} 78.151 \text{ weight.} \\ 12 \text{ ratio.} \\ \hline 937.812 \\ 67.5 \\ \hline 80)1005.312 \\ .7854 \overline{) 12.5664} (16 = 4 \text{ in. diam.} \\ \hline 7854 \\ \hline 47124 \\ 47124 \end{array}$$

FOURTH.—The same data to find the distance on the lever, between fulc. and valve, to permit the valve to rise at 80 lbs. per square inch.

Multiply the distance of the centre of gravity of the lever by the weight of the lever, $18 \times 10.5 = 189$ lbs. Multiply the length of the lever by the weight, $36 \text{ in.} \times 78.151 = 2813.436$; add to this the above $189 = 3002.436$; call this No. 1. Then multiply the area, 12.5664, by the given pressure, 80 lbs., 1005.3120 , subtract the weight of valve and stem, $4\frac{1}{2}$ lbs. = 1000.8120; call this No. 2. Then divide No. 1 by No. 2; the quotient is 3 inches length of short arm.

FIFTH.—The same data to find the point on the lever to hang the weight of 78.151 lbs. to carry 80 lbs. per square inch.

Area, $12.5664 \times 80 = 1005.3120$; deduct the constant, $67.5 = 937.812$. Multiply this by 3 and divide by $78.151 = 36$ inches, the distance to hang the ball.

The system adopted by the Board of Supervising Inspectors of the United States: At what distance from fulc. must a weight of 100 lbs. be placed to allow the valve to rise at 75 lbs. per square inch? $\frac{F}{4} \parallel \frac{15}{3 \text{ lbs.}} \times \frac{1}{4} \text{ lbs.} \parallel$ Area, 12.5664, say $12.56 \times 75 = 942$; call this

No. 1. Then multiply the centre of gravity of the lever, 15 in., by the weight of the lever, 7 lbs. = 105; divide this by the distance of valve from fulc. = 26.25; add weight of valve and stem, 3 lbs. = 29.25; call this No. 2. Then divide the distance of valve to fulc. 4 inches, by the weight of the ball in pounds, $100 = .04$; call this No. 3. Then subtract No. 2, 29.25, from No. 1, $942.00 = 912.75$, and multiply by No. 3, which is .04, which gives $36\frac{1}{10}$ in., or $36\frac{1}{2}$ in. plus from fulc.

How to find the area of opening in square inches of a safety valve 3 in. diameter and a bevel of 45 degrees, depth of seat $\frac{3}{8}$, and a $\frac{1}{4}$ in. lift. Multiply the diameter, 3 in., by the lift, $\frac{1}{4}$ in. or $\frac{25}{100} = .25$ multiplied by the constant, $2.22 = 1.6650$, and to this product add the square of the lift, $.25 = .0625$, multiplied by half the constant, or $1.11 = .069375$ equals 1.734375 , or $1\frac{1}{4}$ square inches opening. Same data for $\frac{1}{2}$ inch opening $3 \text{ in.} \times .5 = 1.5 \times 2.22 = 3.330$; and .5 squared = $.25 \times 1.11 = .2775$ added to the above $3.330 = 3.6075$ square inches, etc.

Setting Corliss Engine Valves.

In all Corliss engines you will find four valves. The two at the top on a horizontal engine are steam valves, those at the bottom the exhaust. On one side of the cylinder you will find a wrist plate, which is connected on one side by suitable rods to the eccentric motion, and on the other side by rods to the four valves. Those at the bottom are permanently attached to the exhaust valve stems, while those at the top are attached, by means of locks capable of releasing, to the steam valves. All of this will be found on the back side of the engine. Now go to the other or front side and remove the bonnets from the ends of the valve chambers, being careful not to drop the hollow flange pieces that turn in the bonnet and fit into grooves in the ends of the valves. You will probably find marks on the end of the valve that will show you the position of the steam cavity, also marks on the edge of the valve chamber showing the position of the parts to the cylinder. If these marks are not there, make them at once. On the stud on which the wrist plate turns, there is, or should be, a mark showing its centre position and two other marks showing its extreme travel. Bring centre marks to position and clamp wrist plate, then adjust valves by lengthening or shortening the rods until the valves will cover the steam ports a little, say $\frac{1}{8}$ or $\frac{1}{4}$ of an inch. Now will be a good time to experiment a little. Find how much your valve moves at one turn of its rod, and you will then be able to tell how much you are moving your valve when you attempt to adjust it after the bonnet is on.

Now set the exhaust valves the same, only if it is a non-condensing engine you had better leave both of the ports a little open, say about as much as the steam valves have of lap. Now loosen up the wrist plate and notice the movement of the valves as it is moved backward and forward. You will see that the steam and exhaust valves are open at opposite ends at the same time. You will see that the steam can be going into the cylinder at one end and the exhaust going out at the other. That is right, so put on all the bonnets except the one over the steam valve on the crank end. Bring the engine crank on to a centre, and place the eccentric at about right angles to it, either ahead or behind, according to the way the engine is to turn. There is usually a rocker arm between the eccentric and wrist plate. This is for the double purpose of relieving it of part of the weight and giving it more motion. These two rods should now be connected and the eccentric move until the valve is brought line to line. Now put on the last bonnet and try steam. If you are a good engineer she won't run to suit you, and you will improve it by further adjustments, giving perhaps more lead or more compression.

Stop and think what the result will be before you adjust with any of the rods. Reason like this: If I shorten the exhaust rod she will not release so quick and will close quicker, so I will get more compression. If you think a good deal and reason correctly, you will get that engine to run very well, but probably not just right until you attach an indicator.

To Keep Machinery from Rusting.

Take an ounce of camphor, dissolve it in one pound of melted lard; take off the scum and mix with as much fine black lead as will give it an iron color.

Clean the machinery and smear it with this mixture, after 24 hours rub clean with a soft linen cloth.

To Back Out Bolts.

When driving out bolts, without protection for the thread, strike the hardest blow you can with a heavy hammer. Light blows with a small hammer will upset or rivet the bolt.

To Wipe a Lead Joint.

Scrape the ends for about one and a quarter inches and paint with lamp black and oil the part to be soldered; also rub the parts to be soldered with tallow for a flux after being scraped. Open one end like tunnel with a wooden tampion and cut the end to be joined to a taper. Hold the ends well together with clamps if you have no helper.

Take several folds of canvas or bed-ticking, well greased, in your left hand which is held under the joint and with a small iron ladle pour molten solder over the joint. A hot soldering iron remelts it and forms a sound joint which is finished off with the pad.

Mixing Different Metals.

When mixing different metals, melt the one having the highest melting point first and then add the others in the order of their melting points, heating them first in order to prevent their chilling the metal already melted. Should the metals tend to volatilize or to form an oxide, keep the surface covered with a layer of fine charcoal. Be sure and skim the metal before pouring.

Melting together two parts of lead and one of tin makes an excellent plumbers' solder.

Tinman's solder is made by melting together two parts of tin with one of lead.

To braze sheet iron make a solution of borax and water for a flux; mix it with brass spelter, lay thickly on the iron and melt over a clear forge fire; remove the work from the fire as soon as the spelter has run into the joint.

Lime, Sand and Plaster.

Three and one-half barrels of lime will do 100 square yards plastering, two coats.

Two barrels of lime will do 100 square yards plastering, one coat.

One and one-half bushels of hair will do 100 square yards plastering.

One and one-quarter yards good sand will do 100 square yards plastering.

One-third barrel of plaster (stucco) will hard finish 100 square yards plastering.

One barrel of lime will lay 1,000 bricks. (It takes good lime to do it).

Two barrels of lime will lay one cord rubble stone

One-half barrel of lime will lay one perch rubble stone (estimating quarter cord to perch).

To every barrel of lime estimate about five-eighths yards of good sand for plastering and brick work.

Cement.

One and one-quarter barrels cement and three-quarters yard sand will lay 100 feet rubble stone.

Floor, Wall and Roof Measure.

To find the number of square yards in a floor or wall: Rule—Multiply the length by the width or height (in feet) and divide the product by 9; the result will be square yards.

Proper covering of a boiler and steam pipes save from twenty to thirty per cent. of fuel.

Remember that a slight leak from a bad joint in a boiler may cause a severe local grooving.

When pumping hot water, a stand pipe open at its upper end and extending a little above the source of supply, should be connected to the supply pipe near the pump; the rising and falling of the water in this pipe will ease the pump and allow the steam rising from the water to escape freely.

When the pulsations of an engine can be seen in a boiler, the latter is too small for its work.

A thin coating of glycerine on both sides of a pane of glass will prevent the condensation of steam which would otherwise obscure it.

A permanent and durable joint can be made by the use of asbestos mixed with sufficient white lead to make a stiff putty. It will resist any amount of heat and is unaffected by steam or water.

Cast iron fly-wheels should not be given a greater speed than 80 feet per second to be perfectly safe.

Vaseline will keep polished tools from rusting better than anything else.

CEMENTS.

Ninety-eight parts fine iron borings; one part flour of sulphur; one part sal ammoniac. Mix, and when required for use, dissolve in boiling water. This cement sets quickly.

If required to set slowly, which makes a better joint, 197 parts iron borings; one part flour of sulphur; two parts sal ammoniac. When required for use, mix with boiling water. The iron borings used for making joints should be perfectly free from grease or oil.

For Turned and Bored Joints.

One part white lead; one part red lead. Mix with boiled linseed oil to the proper consistency.

For Stopping Joints, Etc.

White lead in oil, mixed with enough white sand to make a stiff paste. This grows hard by exposure, and resists heat, cold and water.

For Steam and Gas Pipes.

The following mixture, it is said, makes a cement for steam and gas pipes impermeable by air or water, hot or cold. Six parts of finely powdered graphite, three parts slacked lime, and eight parts of sulphur are mixed with seven parts of boiled oil. The mass **must** be well kneaded until the mixture is perfect.

Glycerine Cement.

A valuable cement for general use, stopping leaks in tanks, joining chemical apparatus, such as glass and brass; in fact, closing cracks and stopping leaks in almost everything, may be made by mixing commercial glycerine and litharge to the consistency of dough. It may be somewhat improved by using Portland cement and litharge, equal parts, when the joints or cracks are large.

This will harden under water, and will stand a high temperature: also the action of hydro carbon vapors.

To Resist Fire and Water and Harden Quickly.

Two parts finely sifted unoxidized iron filings.

One part, perfectly dry, finely powdered loam.

Knead the mixture with strong vinegar, into a homogeneous plastic mass, to be used as soon as made.

Millboard, for Jointing Flanges, Lids, Etc.

Millboard steeped for a short time in warm water to render it pliable, and coated with red or white lead, is far superior to cement for attaching flanges, lids, etc. It makes a better and more durable joint, and in the case of flanges, is not cracked, as cement often is, by the setting of the pipes in the ground.

Liquid for Pressure Gauges.

When petroleum is used in pressure gauges, all impurities will be precipitated and collected at the bottom of the tube, leaving the glass perfectly clear. Where water is used, a weak solution of sulphuric acid will effectually cleanse the glass.

Red Lead

should always be mixed with boiled linseed oil. Other oil can be made to answer, but not so well.

The Weight of a Fluid Ounce.

The Troy ounce weighs 480 grains; the Apothecaries' ounce weighs 480 grains; the Avoirdupois ounce weighs 437.5 grains; the Imperial fluid ounce weighs 437.5 grains; the Wine Measure ounce weighs 455.7 grains. The grain, ounce and pound Troy, and the grain, ounce and pound Apothecaries' weight, are precisely the same. 175 pounds Troy equal 144 Avoirdupois. A grain is precisely the same weight in Troy, Apothecary and Avoirdupois weight.

Mortar.

One part lime, three parts river sand.

One part lime, two parts sand, one part blacksmith's ashes, or coarsely ground coke.

Coarse Mortar.

One part lime, four parts coarse sand.

Hydraulic Mortar.

One part blue lias lime, two and a half parts burnt clay, ground together in a mortar mill, or one part blue lias lime, six parts sharp sand, one part puzzolana, ground together.

Concrete.

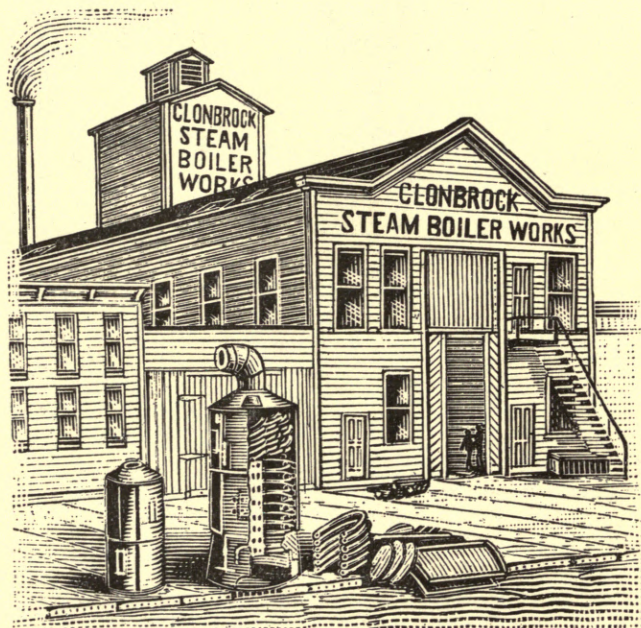
One part lime, four parts gravel, two parts sand.

Plastering.

1 bushel of cement, or 1.28 cubic feet will cover	}	1 in. thick.	$\frac{3}{4}$ in. thick.	$\frac{1}{2}$ in. thick.
1 cement and 1 sand		$1\frac{1}{2}$ sq. yd.	$1\frac{1}{2}$ sq. yd.	$2\frac{1}{2}$ sq. yd.
1 cub. yd. of lime, 2 yds. of sand and 3 bushels of hair will cover	}	$2\frac{1}{2}$	3	$4\frac{1}{2}$
		75 yds. sup. render and set on brick, or 70 yds. on lath.		

Mason Work—Brick.

One and one-eighth barrels lime and five-eighths yards sand will lay 1,000 bricks. One man will lay 150 feet of stone per day with one tender.



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